Public Utility District No. 1 of Pend Oreille County

Box Canyon Hydroelectric Project
FERC No. 2042

Erosion Control, Prevention, and Remediation Plan
Box Canyon Reservoir

P.O. Box 190
130 N. Washington
Newport, Washington 99156

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1. INTRODUCTION

The Box Canyon Hydroelectric Project (Project) license issued by FERC on July 11, 2005 (112 FERC 61,055), required that Public Utility District No. 1 of Pend Oreille County (District) file a plan to monitor shoreline erosion throughout the Project reservoir (Article 408*)*. The purpose of the erosion monitoring was to determine the location and rate of shoreline erosion that is occurring at various points throughout the Box Canyon Reservoir (BCR) and the degree to which Project operations contribute to such erosion. Sixteen sites on the reservoir have been monitored since the spring of 2000, and an additional sixteen sites have been monitored since fall 2001. The District added seven sites on Kalispel Indian Reservation (KIR) lands in 2006, and three sites on Colville National Forest (CNF) lands in 2007. Permission to monitor one site was revoked in 2007, and a site was destroyed in 2008 (both of these were on private lands), bringing the current total number of sites monitored to 40.

The Box Canyon Project affects location and rate of erosion primarily by having raised the water surface elevation of the river - now a reservoir - above those levels that would have occurred naturally, and through increased wave action, the primary process that erodes Box Canyon Reservoir shorelines. However, as explained in brief below, the project does not affect water surface elevations once the flow of the river reaches certain high levels. Shorelines at higher elevations were eroded, at least to some extent, by the river at high seasonal flows prior to construction of Box Canyon Dam.

Box Canyon is operated as a run-of-river hydroelectric project. The spillway gates at Box Canyon Dam (river mile 34.1) are operated so that water surface elevations at Cusick (river mile 70.1) caused by project-induced backwater do not exceed elevation 2041. To meet this constraint, spillway gates at the dam must be opened to lower reservoir elevations (drawdown) when river flows begin to exceed 68,000 cfs. As flows increase above 68,000 cfs, the gates are alternately raised in each spillway bay, until all gates are removed and the river free flows over the spillway at 90,000 cfs. At 90,000 cfs, river elevations then become regulated by a naturally occurring narrow entrance to Box Canyon, located about one-half mile upstream from the dam.

Box Canyon Dam drawdown at high flows affects river elevations downstream from river mile 55 differently than upstream of river mile 55. As the gates at the dam are progressively opened as flows increase above 68,000 cfs, reservoir elevations are most affected (i.e., drawn down) near the dam, and the effect decreases moving upstream to river mile 55. Upstream from river mile 55, river stage continues to increase with increasing flow above 68,000 up to 90,000 cfs at which point the dam, with all gates removed, has no effect on river surface elevations. As a result of the constraints and operating procedures at the dam and the natural effects of Box Canyon, water surface elevations at flows exceeding 90,000 cfs are unaffected by Box Canyon Dam for the portion of the reservoir upstream from river mile 55, and above 68,000 cfs between river mile 55 and river mile 42. From river mile 42 to Box Canyon (river mile 35), flows must exceed 100,000 cfs before natural river levels exceed elevations affected by backwater from the dam.

This Erosion Control, Prevention, and Remediation Plan (ECPRP) fulfills the erosion control, protection and remediation requirements in License Article 408(b), the DOI 4(e) Conditions in Appendix A, and the Forest Service 4(e) Conditions in Appendix B of the project License Order, as described below. It provides specific approaches for remediation of shorelines that are in state, private and Tribal ownership, and those that are managed by the US Forest Service.

2. BOX CANYON PROJECT LICENSE EROSION CONTROL REQUIREMENTS

2.1. License Article 408 Erosion Control and Monitoring

Article 408(a) of the Box Canyon license required the District to monitor erosion around the reservoir. Article 408(b) required that the District file for Commission approval a plan to provide "erosion control, protection, and restoration of areas around the project reservoir with high, moderate, low, and non-active erosion rate categories." The plan must be developed "based on information on areas where erosion can be clearly attributed to project operations." Project-caused erosion is to be determined based on the District's shoreline erosion monitoring information. Consistent with the FERC License Article 408, this ECPRP provides for erosion remediation of project related erosion.

2.2. License Appendix A, DOI 4(e) Conditions

DOI Conditions 3.A through 3.F address reservoir drawdown limitations and reservoir level monitoring requirements. Condition 3.E addressed Geotechnical Engineering Study requirements.

The District obtained the required approvals, implemented the Geotechnical Engineering plan, and submitted a draft of its findings to the Box Canyon Technical Committee Erosion Subcommittee on June 14, 2010. No comments on the Draft were received by the District, and the final Geotechnical Engineering Study report was filed with FERC in August 2010 (See Appendix D).

DOI Condition 3.F. paragraphs 1-7 specified various shoreline erosion monitoring requirements. Each of these requirements was addressed within the District's Shoreline Erosion Monitoring Plan, approved by FERC, and has been implemented by the District. Condition 3.F. paragraph 8 requires that the District "identify remedial measures." This ECPRP identifies remedial measures based on the previous shoreline erosion monitoring and describes the agreed level of funding for these sites.

2.3. USDA Forest Service Section 4(e) Conditions 8 and 9

Forest Service 4(e) Condition No. 8 (in License Appendix B) contains the Forest Service requirements for the Erosion Monitoring Plan. Condition No. 8 requires:

1. Develop the Erosion Monitoring Plan in cooperation with the USDA Forest Service.
2. Submit the plan to a peer review process approved by the USDA Forest Service.
3. After peer review, the USDA Forest Service will have final approval of the plan for National Forest System lands.

The District conducted a peer review process, approved by the Forest Service, and modified the erosion monitoring plan as recommended. The Forest Service approved the plan in a letter dated August 24, 2006 addressed to the District.

The final Erosion Monitoring Plan was approved by FERC on August 14, 2007. The plan contained the following objectives per License Article 408 and the requirements of the 4(e) Conditions from the DOI and USFS:

1. Determine the rate of shoreline erosion at monitored locations throughout the reservoir.
2. Determine the relative importance of operative erosion processes at each monitored location; determine when they occur seasonally and through longer intervals of time in association with annual hydrologic variability.
3. Determine the relative rate of erosion for all project shoreline locations through extrapolation of results from monitored locations based on similarity of location, geomorphic, and hydrologic circumstances.
4. Determine the degree to which project operations contribute to such erosion.

Section VI of the District's monitoring plan provided extensive discussion of how the District's monitoring information will be developed and used to determine the degree to which the project contributes to erosion.

Forest Service 4(e) Condition No. 9 required that erosion remediation be planned and implemented on an accelerated schedule at the Ruby Ferry and Edgewater Campground sites on Forest Service lands along the BCR. The District completed remediation at these sites in 2009.

Consistent with the FERC License Article 408, DOI, and Forest Service mandatory conditions, this ECPRP identifies specific sites to be remediated on Forest Service lands along the project, and provides procedures for determining the District's funding responsibilities at these sites.

3. SHORELINE EROSION MONITORING FINDINGS

The objectives of the District's shoreline erosion monitoring are to quantify the rate of erosion, identify its causes, and estimate the degree to which the Box Canyon Project contributes to this erosion. In addition to formally reviewing conditions along all Box Canyon shorelines at least once per year, the District currently monitors erosion at 40 sites. These sites are surveyed at least twice per year in order to precisely profile the shoreline surface and calculate rate of erosion. The annual shoreline erosion monitoring reports also provide figures representing the precise shape of the monitoring site transect profiles to document streambank recession, if any, for each of these monitoring sites, along with discussion of where erosion occurs on these profiles.

The District's annual shoreline erosion monitoring reports provide rate-of-erosion results presented as depth of erosion as measured across the entire streambank profile. These measures represent average rate of bank recession at the monitoring sites. These rates range from no erosion to a maximum of 0.20 feet per year at Site 57). Averaged over 40 sites, this entire-profile-based approach yields a reservoir-wide average annual shoreline recession rate of 0.04 feet. Although not all sites have a common period of measurement (i.e., some sites have been measured for more years), and the sites are not randomly located, this value provides a meaningful order of magnitude estimate of this form of erosion for the reservoir. Data for each of the monitoring sites is provided in Appendix B, Table 1.

Another measure of bank recession, the more common approach for reservoirs reported in the literature, is provided by measurement of change in the point located at the "top" of the streambank. However, and particularly because rates of erosion for Box Canyon Reservoir occur at rates of hundredths to at most two-tenths of a foot per year, precise identification of the top-of-bank position from one year to the next is difficult. Nevertheless, measurable bank recession can be recognized to have meaningfully occurred at 6 monitoring sites during 2008 through 2010, with a maximum observed rate of 0.59 feet per year. The years 2008 through 2010 were examined because the surveys are most accurate for these years and could be graphed most accurately, and a somewhat high and somewhat low peak flow occurred during the interval. Averaging these results over the 35 sites that have not been remediated yields a reservoir-wide average shoreline recession rate of 0.06 feet per year for these three years, again providing a meaningful order-of-magnitude estimate of bank recession for the reservoir (Appendix B, Table 2).

The Shoreline Erosion Monitoring Plan also requires review of rates of shoreline erosion reported within the literature, and comparison to those developed for Box Canyon Reservoir. Table 1 provides the Box Canyon rates in comparison to rates reported for twelve lakes and reservoirs, all of which are affected by dams and glacial deposits, much like those forming the shores of Box Canyon Reservoir. Table 1 indicates that rates developed from Box Canyon Reservoir monitoring data for both vertical erosion and bank recession are substantially lower than reported for any of the reservoirs located within the literature. These comparisons should be regarded cautiously. The reservoirs studied and the locations where erosion rates are documented generally were not selected randomly, and bias to problem areas and areas eroding rapidly may occur for several of these studies. Nevertheless, Table 1 demonstrates that rates of erosion recorded for Box Canyon Reservoir even for areas mapped as "high" are low when compared to the rates reported for other reservoirs.

Table 1. Erosion rates of reservoirs affected by glacial deposition

Reference	Location	Vertical Erosion (Ft./yr.)	Bank Recession (Ft./yr.)
McGreer, 2011	Box Canyon Reservoir, WA	0.0 - 0.20 mean = 0.04	0.0 – 0.59 mean = 0.06
Riedel, 1990	Ross Lake, WA	2.8 - 9.2	0.2 - 5.5[1]
Riedel, 2006[2]	Ross Lake, WA	n/a	0.8 - 4.2
Riedel, 2006[3]	Lake Chelan, WA	2 - 4	0-4.0
Gatto and Doe, 1983[4]	Rufus Woods Lake, WA	n/a	0-8.0
Gatto and Doe, 1983	Lake Pend Oreille, ID	n/a	0-5.0
Gatto and Doe, 1983	Berlin Lake, OH	n/a	0-5.0
Gatto and Doe, 1983	Big Sandy Lake, MN	n/a	0-2.0
Gatto and Doe, 1983	Orwell Reservoir, MN	n/a	0-6.0
Gatto and Doe, 1983	Oahe reservoir, MN	n/a	0-39.0
Gatto and Doe, 1983	Lake Sakajawea, ND	n/a	0-17.0
Gatto and Doe, 1983	Fort Peck Reservoir, MT	n/a	0-3.0
Saint-Laurent, 2001	Baskatong Reservoir, Quebec	n/a	<0.25-1.5 Mean ~= 0.23[5]
Dorava and Moore, 1997	Skilak Lake, AK	1.0-5.0	n/a

In 2006, subsequent to the peer review of the shoreline erosion monitoring procedures, the District examined its erosion monitoring rate data in relation to shoreline site characteristics. Erosion rates in relation to shoreline characteristics were again been examined following analysis of data collected through 2009. This analysis is summarized briefly here and is included in more detail as Appendix B.

Erosion rates do not vary systematically with river mile along Box Canyon Reservoir, or with the surficial geology of its shorelines (Figure 1, Appendix B). Reservoir elevation above natural and maximum variation in pool elevation through the year do vary systematically through the reservoir by river mile, but given that erosion rates do not, it follows that they also do not vary in relation to pool elevation and extent of pool variation. Erosion rates likely fail to correlate to geologic type because nearly the entirety of the shoreline was formed by glaciofluvial deposition.

Box Canyon Reservoir shoreline erosion rates have also been examined in relation to individual shoreline characteristics. Collectively, these relationships illustrate that rates of erosion measured at the monitoring sites are related to the MP-1 erosion rate / severity ratings (Figure 2, Appendix B) and to the Appendix A shoreline erosion rate maps (Figure 3, Appendix B). However, no single site characteristic consistently indicates rate of erosion along the reservoir. In general, poorly vegetated and steep sites tend to erode most rapidly. Terracing of shorelines

[1] Estimated
[2] Reported as "observed" within peer review comments submitted to the District
[3] Reported within erosion monitoring plan peer review comments to the District
[4] Erosion rates reported by Gatto and Doe are estimated from multiple aerial photo transects
[5] Mean computed with 11 <0.25 values counted as zeros

by waves, and to a lesser degree by river current, followed by toppling of undercut banks is the predominant form of erosion along the reservoir. Groundwater emergence as river flows decrease and reservoir water elevations commensurately decrease – generally following spring seasonal high flow – decreases soil strength and acts interactively with other erosion processes. Rilling and raveling are important processes in some locations, particularly where shoreline soils are sandy. Grazing and the associated disturbance of vegetation and soils contribute to substantially increased erosion of some shoreline areas.

Waves are most often cited within the literature as the primary cause of shoreline erosion, with wind-formed waves generally found to be the single most important cause. However, waves created by boats can also be important sources of shoreline erosion and can be as or more important than wind waves; this is often the case for Box Canyon. The District studied Box Canyon Reservoir effects upon waves and associated erosion, finding that increases in wave power exerted on shorelines attributable to the presence of the reservoir varied substantially with location. Total wind- and boat-wave power due to the reservoir was found to have increased by as little as 4 percent within the Cusick Basin portion of the reservoir, and by as much as 127 percent near Ione (Figures 14 and 15, Appendix B) where boat-waves were most important.

The District also studied reservoir effects upon groundwater and shoreline bank stability within the Cusick Basin area, as required by the Department of the Interior, finding that normal operation (i.e., non-emergency) of Box Canyon Dam and the reservoir have no effect upon groundwater levels and bank stability relationships within the Basin (Appendix D).

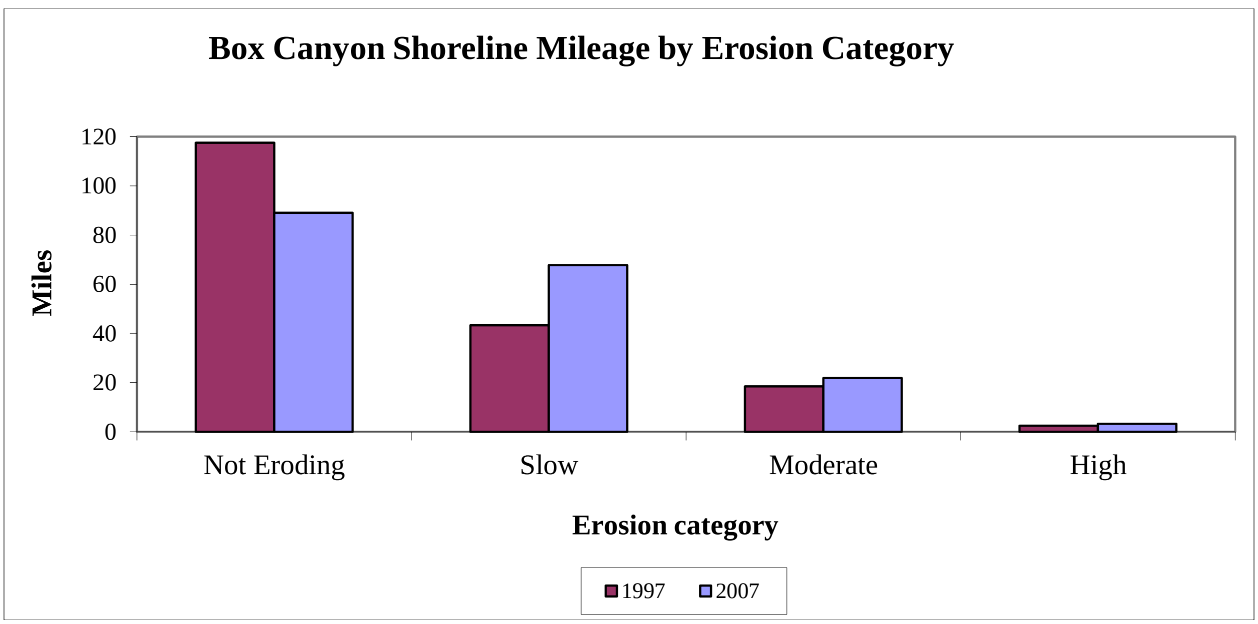
Article 408 (a) of the license requires that the District provide assessments categorizing erosion rates into low, moderate, and high. The District provided an initial classification in 1999 based on field observation of shoreline soils, vegetation, evidence of slumping and sloughing, bank overhang and undercutting, shoreline steepness, and other geomorphic indicators of erosion. This initial effort to classify the project shorelines into erosion rate classes allowed location of monitoring sites throughout the reservoir and in a variety of erosion circumstances. Subsequent to the peer review of the District's erosion monitoring plan completed in July 2006, the District developed an erosion rate/severity rating process, the MP-1 Erosion Process and Rate Evaluation Index that allowed more systematic and reproducible classification of project shorelines into rate classes. The MP-1 rating process provides a systematic means for rating the relative level of activity (i.e., importance) of various indicators of the presence and/or likelihood of erosion process by assigning a quantitative score to each factor. The score for each factor is summed to provide the relative index of erosion activity at each site evaluated. Scores of <3 indicate that a site is likely not eroding, scores of 3 to 12 indicate low rates of erosion, scores of 13 to 21 indicate moderate rates of erosion, and scores >21 indicate high rates of erosion.

The erosion rate data and MP-1 ratings were compared to the rate classes as originally mapped in 1999, and the mapping was systematically adjusted. At each monitoring site, the MP-1 rate class and the measured erosion rate class were compared to the 1999 map class. If both MP-1 rate and the measured erosion rate consistently had a higher (or lower) rate than the 1999 mapped rate, then the mapped rate was adjusted. Otherwise, the original mapping was not changed. Additional details regarding this adjustment were provided within the 2008 Shoreline Erosion Monitoring Annual Report.

The MP-1 evaluation process was also applied to the remainder of the shoreline. The procedure for an individual mapping unit was first to review its mapping boundaries for general reasonability. Then the mapping rate class was compared to the Form MP-1 rating. If results yielded at any nearby monitoring stations with similar soil, geologic, and landform conditions indicated that a map change may be in order for the area, or if informal review of MP-1 indicated that the area had any likelihood of being different than the class previously mapped, an MP-1 review at a representative location within the mapping unit was completed. Boundaries between map units were then also adjusted reflective of these field observations. Based principally upon the results from these MP-1 evaluations, the Erosion Occurrence and Hazard Maps were revised in December, 2007, and were included with the 2008 Annual Shoreline Erosion Monitoring Report and are again provided here as Appendix A.

Figure 1 demonstrates that these reevaluation efforts resulted in substantial reclassification of the reservoir shorelines. Considerable length of shoreline originally classed as "not eroding" was recognized as experiencing at least some degree of erosion and was reclassified from "not eroding" to "slow," or even "moderate." Total length of shoreline increased for all classes except "not eroding," which decreased by 28.5 miles (24%).

Figure 1: Box Canyon shoreline mileage by erosion rate class, 1999 mapping compared to December 2007 revised mapping



4. DETERMINING THE DEGREE TO WHICH THE PROJECT CAUSES OR EXACERBATES EROSION

Article 408(b) of the License requires that this erosion control plan identify the degree to which the project causes or exacerbates erosion. Determining this share is particularly difficult for Box Canyon Reservoir. Erosion occurs on essentially the same shoreline landforms, locations, and elevations as it did prior to the project, because stage is elevated by the Dam to a limited degree, and because once flow of the Pend Oreille River reaches 70,000 to 100,000 cfs, river stage is unaffected by the Dam. Further complicating these determinations, the amount of erosion that any one process contributes to total bank erosion of Box Canyon Reservoir shores - like all reservoir shores - cannot be isolated, because the contributing processes are interdependent. Processes generally occur simultaneously at a given location, and are often influenced by a combination of causal mechanisms also often occurring simultaneously and interactively. Nevertheless, the District's shoreline erosion monitoring plan provides detailed procedures for determining the degree to which the project causes or exacerbates erosion that can be systematically applied to any location along reservoir shorelines.

To address the degree to which the project causes or exacerbates erosion, the District employs the shoreline erosion profiles developed at each of the monitoring sites in conjunction with river stage duration curves to identify the percent of time that the profiles are exposed to river waters for both the "with" and "without" project cases. This analysis, coupled with determination through monitoring and modeling of project-related wave power, allows calculation of an index of "project share" of erosion at each site. Applying these procedures, the *preliminary* project share of exposure adjusted for increased wave power varies from 85 percent (Site 28) to as low as 19 percent (Site 10). A final adjustment is then made qualitatively through consideration by the District and affected landowners of subjective factors that cannot be calculated. These final adjustment factors include considerations such as predisposition to erosion of a site because of erosion that may have occurred there naturally (i.e., is erosion that occurs at today's water levels associated with erosion that occurred prior to the project at lower water levels), and whether the "upslope area" is predisposed to erosion because of project-caused erosion that occurs at lower river stages (i.e., is erosion above maximum project-affected stage accelerated by project-caused erosion at lower stages).

Determining the final degree to which the project causes or exacerbates erosion for specific areas will be based on the preliminary percent project share calculation as reported in the District's 2010 annual shoreline erosion monitoring report. This share may be amended based on analysis of future monitoring data where material change in shoreline erosion circumstances indicate that a new calculation is warranted, and upon site-specific examination of project-area circumstances by the District and affected landowner. Site-specific considerations will include:

- calculation of preliminary project share of erosion at the site - if the characteristics at the site are materially different from those represented by nearby monitoring sites,
- consideration of predisposition to erosion of a site because of erosion that may have occurred there naturally (i.e., erosion that occurs at today's water levels associated with erosion that occurred prior to the project at lower water levels), and

- whether the "upslope area" is predisposed to erosion because of project-caused erosion that occurs at lower river stages (i.e., i**s** erosion above maximum project-affected stage accelerated by project-caused erosion at lower stages).

5. REMEDIATION PLAN AND PROCEDURES ON STATE AND PRIVATE LANDS

The process for remediating erosion on State and private lands includes development of a 5-year plan that will identify location-specific erosion control and remediation projects. For this purpose, the District will use a "rolling" 5-year schedule of projects that, after initial development, will be amended on an annual basis as projects may be completed, as circumstances and/or priorities may change, and as additional projects may be added.

5.1. Collaborative Team

An Erosion Control Project ID Team has been formed to review field circumstances and potential erosion control projects on State and private lands. The ID team will collectively visit and field-evaluate sites per an evaluation process, described below, in order to assess circumstances surrounding potential project sites. Potential sites will be suggested by members of the team in advance of an annual field tour so as to provide a discreet set of sites to be visited and assessed. The ID team will include representatives of five entities: the District, Tribe, Forest Service, WDFW, and WDOE. The District will facilitate and coordinate these field evaluations each year, will tally and communicate the results of the team's evaluations, and will provide the 5-year project schedule based on the team's priorities.

5.2 Procedures for Assessing, Prioritizing, and Selecting Potential Projects

Factors that logically affect a location's priority for implementation of an erosion control project include severity of erosion occurring, practicability of successfully controlling the erosion by arresting the processes causing it, the values to be protected (e.g., cultural, riparian habitat, home sites/real estate, public works), and the timing of necessary implementation requirements (e.g., design, permitting, funding, etc.).

The ID Team members will use a consensus based process to prioritize erosion control projects based on site visits and the following criteria.

1. Severity of Erosion – How bad is the current erosion at the site.
   - Erosion monitoring data
   - On-site conditions

2. Probability of Control – What is likelihood of being able to control effectively.
   - Causal mechanism
   - Review of past projects to address similar erosion control conditions
   - Physical limitations of the site

3. Type of Control/Remediation – What is the best method to control.
   - Hard fix
   - Bio-engineering
   - Physical limitations of the site

4. Values at Risk – What is important about the site to be protected.
   - Public works/infrastructure
   - Wildlife habitat
   - Riparian habitat
   - Fish habitat
   - Cultural Resources

5. Ability to improve values – Will the project (components) contribute to improving values.
   - Wildlife habitat
   - Riparian habitat
   - Fish habitat
   - Water quality – e.g., addresses a TMDL
   - Public works

For each site suggested by any member of the ID team, each member would consider and discuss with the Team the list of factors and other considerations that may apply to a site. Preferably, these discussions would occur during the annual field evaluation trip at the sites visited and considered. This approach best assures open discussion of circumstances and consensus. However, it is recognized that in some instances additional information not available in the field may be needed for a fully informed evaluation of the sites, and that further discussion of site priorities and scheduling may need follow the field assessment trip. It is also recognized that while the ID Team will develop the project schedule, each landowner reserves the authority to approve initiation of any and all projects on that landowner's shorelines.

Consistent with the site selection process described above, the Erosion subcommittee field reviewed three Forest Service and two tribal candidate erosion control project sites, and assigned priorities for scheduling them in October, 2010 (Appendix C).

5.3. Funding Projects on State Lands

The District will participate and cost-share in as many projects per year on State shoreline lands ("public lands") as can be feasibly planned, permitted, and prepared subject to the funding limits described below. Projects submitted for consideration to the District will be ranked by the Erosion Control Project ID Team and listed in order of their priority for completion. This schedule will be amended annually as needed and as projects may be completed, as circumstances and/or priorities may change, and as additional projects may be added through time.

The District will fund projects on public lands commensurate with the degree to which the project causes or exacerbates erosion computed as a reservoir average based on the procedures detailed within the District's Shoreline Erosion Monitoring Plan, and as computed based on the 2010 Annual Shoreline Erosion Monitoring Report. This average project share for the reservoir is 38%. To provide its share of funds for public lands projects, the District will establish a Public Lands Shoreline Erosion Control Fund. The District will establish the fund with an initial contribution of $50,000 during the calendar year that FERC approves the District's ECPRP. At the first of each successive year for the following nine years the District will then provide an additional deposit to the fund to rebuild the fund to an amount not to exceed $50,000. Per this procedure, the District's annual funding obligation will not exceed $50,000 per year and will not exceed a total amount of $500,000 for the first ten years of this plan. However, for a project requiring more than a total District contribution of $50,000, the District may agree to provide an additional $50,000 in a single year, providing that the total District obligation for first ten years of this plan remains limited to $500,000. Funding for any additional projects that may be needed following the initial ten years will be determined at that time.

Allocations from the Public Lands Shoreline Erosion Control Fund will be used to pay for the District's share of costs related to planning, permitting, construction, and monitoring, including surveys, design, HPA, and 404. The public entity owning the shoreline where a project is located is responsible for each of these activities; the District's responsibility is limited to a share of the funding required for these activities.

The Public Lands Shoreline Erosion Control Fund and the erosion control plan will be reviewed every 5 years in conjunction with the updating of the ECPRP. Results of the review will be reported to FERC by the District following a 30-day review period and circulation to the ID Team. Comments received by ID Team representatives, District responses, and District explanation of comment responses and any modifications to the draft review report will be included with the final review report to FERC.

5.4 Funding Projects On Private Lands

For private lands, the District will contribute funding for shoreline erosion control projects for individual landowners. These contributions will be limited to erosion control features of projects, and cannot be used for unrelated or ancillary activities, such as development of shoreline access features (e.g., staircases, walkways, etc.), dock construction, weed control, or other purposes. Contributions will be limited to a single project per landowner, and will be limited to a single amount not to exceed $5,000 or the total cost of the project, whichever is less. To provide this funding, the District will establish a Private Lands Shoreline Erosion Control Fund. The District will establish the fund with an initial contribution of $50,000 during the first calendar year following the year that FERC approves the District's ECPRP. At the first of each successive year the District will then provide an additional deposit to the fund to rebuild the fund to an amount not to exceed $50,000. Per this procedure, the District's annual funding obligation will not exceed $50,000 per year. Allocations from the Private Lands Shoreline Erosion Control Fund will be limited to the District's share of project construction costs (i.e., labor and materials).

Private landowners with Box Canyon Reservoir shorelines may make application to the District for funding for a shoreline erosion control project by providing the District with approved permits from the applicable regulatory authorities (e.g., WDFW, U.S. Army Corps of Engineers, Pend Oreille County). The application process will be open from January 1 through March 31 of each calendar year. Applications received by the District will be date stamped upon receipt at the District's Newport, Washington office. Applications received by the District will be distributed by the District to the Erosion Control Project ID Team which will then screen each application to insure that only projects which meet certain minimum qualifying criteria are accepted for potential funding. Minimum qualifying criteria will be developed by the Erosion Control Project ID Team during calendar year 2011 and will include considerations such as use of appropriate physical and biological control features, likelihood that the design will effectively control erosion at the site, and that the project is proposed for an area having moderate to high rate of erosion per the District's current Shoreline Erosion Hazard and Occurrence Map.[6] Funding for qualified private landowner projects will then be granted to applicants in order of receipt of the application by the District subject to the availability of funding per the District's contribution provisions above, and following demonstration by the landowner that the project has been completed consistent with the application. Completion of the project as designed can be demonstrated to the District with invoices for work accomplished and with photographs of the completed project demonstrating incorporation of the project design features.

6. PUBLIC EDUCATION

The District will develop an educational outreach brochure regarding the District's private landowner erosion control assistance program. The brochure will be made available to local NRCS and extension offices, at the District's Newport, Washington office, and will be distributed to the District's ratepayers as a mailing once each year. The brochure will explain the funding application process, the minimum criteria that a project must meet in order to qualify for District funding, the requirement for regulatory program permits and approvals, and the procedures that the District will follow for reimbursement to landowners.

The District will also provide funding annually to the Pend Oreille Conservation District, which shall be used for a public education program on causes of erosion, bank protection and stabilization techniques, and related issues. It is expected that the Conservation District will in part rely on WDFW manuals and manuals developed specifically for Box Canyon Reservoir, referenced below.

7. REMEDIATION PLAN AND PROCEDURES ON KALISPEL INDIAN RESERVATION LANDS

Pursuant to the Project license and provisions of 4(e) condition 3. F required by the Secretary of the Interior, including requirements to determine the degree to which the project causes or exacerbates erosion, the District has assumed that its erosion control funding responsibilities are

[6] Landowners may appeal to the District for projects proposed for areas not mapped as having moderate or high rates of erosion if they can demonstrate to the District's satisfaction that erosion rates at the project site is occurring at a substantial rate not accurately reflected in the maps. Waiver of the map rate requirement will then be made at the sole discretion of the District.

limited to the percentage of total erosion attributable to the project and do not include that percentage attributable to natural or other non-project related causes. However, the Tribe has completed several erosion control projects over the course of many years and without any District funding. Recognizing these efforts at erosion control and past expenses incurred by the Tribe, the District has agreed with the Tribe to set aside "project share" considerations for future erosion control projects along Tribal shorelines. Instead, the District has agreed to fund certain projects identified by the Tribe according to the following list of projects and schedule over the course of 10 years:

- 2011 Restoration of shoreline Dike Road
- 2012 Continue work on Dike Road
- 2013 Continue work on Dike Road
- 2014 Finish or add more time to complete Dike Road work
- 2015 Calispell Slough restoration work
- 2016 Continue work on Calispell Slough
- Potential additional year of work to finish
- 2017 Campbell Slough N/S Flying Goose Phase I shoreline restoration
- 2018 Flying Goose phase II shoreline restoration
- 2019 Reservation North/Old Dike Spit restoration
- Potential additional year of work to finish
- 2020 Everything listed above not yet completed

These projects represent 16,800 feet of shoreline, or approximately 20% of the erosion currently identified on KIR lands. Once these projects are completed to the satisfaction of the Tribe and the Secretary of the Interior, they will satisfy 4(e) condition 3.F.8 with respect to existing erosion sites on KIR lands. The District will also be responsible for treating any new areas identified through monitoring or other evidence.

The District and the Tribe have estimated the average cost of implementing these measures at no more than $150 per foot, or approximately $2,500,000. The work will be accomplished by the Tribe through use of annual inter-local agreements funded by the District at amounts not to exceed $150,000 per year. The schedule, terms and funding for the annual inter-local agreements may be extended through agreement between the Tribe and the District up to a total of 15 years if necessary to complete these projects.

The Kalispel Tribe's Natural Resources Department (KNRD) agrees that it will make every effort to complete the scheduled work within this time frame barring any unforeseen circumstances. KNRD will secure the necessary permits and design specifications required for successful completion of restoring the shoreline along the Kalispel Reservation.

8. REMEDIATION PLAN AND PROCEDURES ON NATIONALFOREST SYSTEM LANDS

For National Forest System (NFS) shorelines, as for reservation shorelines, the District assumes its responsibility for erosion control funding is limited to the percentage of total erosion attributable to the project and does not include the percentage of erosion attributable to natural or other non-project related causes. The District has to date funded and completed two extensive projects on NFS shorelines along the FS Edgewater Campground and Ruby Ferry parcels in 2009 in consultation with, and permitted by Forest Service staff.[7]

The District has agreed to fund remediation of the areas listed by the Forest Service in their April 11, 2011 proposal. These projects are listed below along with the schedule for their completion.

Pursuant to the Project license and provisions of the Forest Service's Federal Power Act Section 4(e) Condition 9, the District will implement measures at the following sites (Table 2), during the identified years, to address the current level of Project-caused erosion on NFS lands:

Table 2. Forest Service Project Schedule

Project (federal fiscal year)	Total length of erosion (ft)
2012 - 2021	
Riverbend	760
Panhandle	2,820 (1,420 treat, 1,400 plant)
Tiger	750
Total	4,330
2022 - 2031	
Yokum	4000*
Pioneer	2600*

* Preliminary estimate

These projects represent 10,930 feet of shoreline. The District will fund the three Forest Service projects that have been identified for the next 10 years, Riverbend, Panhandle, and Tiger. The District will work with the Forest Service to develop the scope for each of these projects so that the District can include appropriate funds for the project in its budget. Once these projects are completed to the satisfaction of the Forest Service, they will satisfy 4(e) Condition 9 with respect to existing erosion sites on NFS lands. The District will also be responsible for treating any new areas identified through monitoring.

The District is responsible for treating two additional sites, Yocum and Pioneer II, between 2022 and 2031. These two sites will be included in the revised ECPRP developed in Year 2021. The PUD is also responsible for treating any new areas identified through monitoring or other evidence. The cost and schedule for treating these new sites will be addressed in the five- year revisions to the ECPRP as the sites are identified.

Any erosion control funds for a project that are unspent by the Forest Service at the end of five years after they are provided by the District, will be returned to the District in full during the following year.

[7] The District agreed to fund these projects in 2009, prior to determining project share, with the provision that once said project share was developed from the monitoring data, cost in excess of the District's share would be credited to future projects.

9. EROSION CONTROL PROCEDURES

Shoreline stabilization approaches and procedures have been developed by the State of Washington and published in a detailed manual (WDFW et al. 2003). This manual has recently been further adapted for the specific circumstances found for Box Canyon Reservoir shorelines in a second manual, Pend Oreille River in the *Box Canyon Reservoir Riverbank Stabilization Guidelines* (WDFW 2007). The manual provides detailed discussion of shoreline stabilization techniques specifically applicable to Box Canyon Reservoir shorelines and that are generally approvable by the WDFW. Shoreline cross section diagrams are provided that show stabilization techniques that use combinations of rock revetment, bioremediation using geotextile soil reinforcement and vegetative plantings, and reconstructed / re-shaped banks. The Montana Department of Natural Resources and Conservation (DNRC) (Montana, 2001) also provides useful guidance regarding use of "soft" (not rock) bioengineering streambank stabilization techniques, such as fabric-wrapped soil blankets, bundles of willow, dogwood, or cottonwood bundled cuttings (wattles / fascines), live cuttings, and brush blankets.

FERC at section 408(b) of the Project license required that the District investigate the feasibility of incorporating prairie cordgrass for erosion control. Although prairie cordgrass is not mentioned in the WDFW or Montana shoreline stabilization publications, the USDA NRCS (1989) notes that prairie cordgrass (Spartina pectinata) provides "good shoreline cover, and contributes to wave energy dissipation." Thus, prairie cordgrass, along with several other grass species, could be incorporated into shoreline stabilization projects along Box Canyon Reservoir shorelines.

10. FUTURE MONITORING

The Shoreline Erosion Monitoring Plan required several studies and tasks that have been completed and require no further action. These completed studies and tasks include the drawdown effects on slope stability study, the landslide inventory and cause study, the wave power study, and materials stratigraphy documentation. District activities related to these completed studies and activities will be discontinued upon approval of this Erosion Control, Prevention, and Remediation Plan. Additionally, not all of the current sites monitored through detailed shoreline surveying techniques contribute information commensurate with the difficulty and expense of survey and data analysis required. Some sites have not and are unlikely to erode, some are clustered and duplicative, some have been disturbed by construction, and some have been effectively remediated. Therefore, the District will discontinue surveyed-transect monitoring at a total of 14 sites. However, other shoreline erosion monitoring activities continue to provide valuable information to the District and shoreline owners. Accordingly, the District will to continue monitoring BCR shorelines per the following outline:

- Professional assessment of drawdown or flood effects, and inspection of shorelines for new areas of erosion.
    - These assessments will continue to be conducted on an annual basis. In high peak flow years and/or if drawdown in excess of 3"/hour occurs, as many as three assessments/inspections per year may be necessary and will be conducted.
- Surveyed monitoring sites

  - Surveyed monitoring of 26 sites will continue to be conducted. Recommendations regarding future monitoring are detailed in the following schedule, Table 3.
- Groundwater monitoring
  - The District is required by FERC to monitor for erosion and the effects of the interim drawdown limitations authorized by FERC on May 26, 2009. If the District demonstrates to the Secretary of the Interior (Secretary) over this interim period that the rate of erosion is not affected by these operations, then operations as described in section 3.A.ii) shall become standard practice beginning May 1, 2015, after receiving approval from the Secretary. Accordingly, the District will continue to monitor groundwater elevations at the six monitoring wells, and to analyze these data in conjunction with river surface elevation as affected by operation of Box Canyon Dam, through April, 2015.
- Erosion control project monitoring

Effectiveness of each erosion control project cooperatively funded by the District will be monitored. Projects on private lands will be monitored by discussion of each project with the project's landowner, annual inspection, and photo-documentation. For public lands projects, the ID Team and/or the Erosion Subcommittee will discuss potential approaches and determine specific courses of action. The ID Team may also develop specific success criteria for a project (e.g., percent planting survival, percent vegetative cover, effectiveness of physical erosion control installations), and monitoring procedures that allow evaluation relative to each criterion of effectiveness.

Forest Service Condition No. 9 requires site-specific effectiveness monitoring plans. A plan was developed and implemented for the Forest Service Ruby Ferry project. For the Edgewater Project, continued monitoring of two surveyed sites was deemed adequate, and the District will continue this monitoring into the foreseeable future.

The current shoreline erosion monitoring plan requires the District to survey each site twice per year; once in the summer following annual spring peak river flows, and once in the fall. Eight of the 40 sites are also surveyed in the spring prior to peak river flows. These multiple surveys per year have proved problematic, and the data provide little or no additional information above that which is obtained from once-per-year surveys. Problems arise because the summer surveys are often not completed until mid-August, and the fall surveys must begin in October, which does not provide a sufficient interval of time between surveys to observe any meaningful change in the shoreline. Even with the fall surveys beginning in October, snow and ice have formed on shorelines in some years before surveying at all sites has been completed, and the results from these surveys are then rendered erroneous and must be disregarded. Therefore, the District proposes to discontinue all but a single annual survey to be completed during August through September of each year.

Table 3. Post-erosion control and remediation plan shoreline erosion monitoring schedule

Site	Discontinue Monitoring?	Notes
1	Yes	Landslide. Continue to observe for landslide activity.
29	Yes	Landslide. Continue to observe for landslide activity.
2	Yes	Remediated. Area upslope from remediation has not been eroding.
30		Remediated, but upper slope not subject to reservoir waters will continue to erode.
50		Remediated, but upper slope not subject to reservoir waters will continue to erode.
43T	Yes	Remediated with sea wall. Upper-slope landslide not related to reservoir.
44	Yes	Deep-seated slump-earthflow not related to project.
7	Yes	Deep-seated slump-earthflow not related to project.
33	Yes	Private lands, slow, rate of erosion determined.
46	Yes	Private lands, moderate, rate of erosion determined.
10	Yes	1 of 3 clustered sites on USFS. Slow. Discontinue 2 of 3. Retain most active Site 49.
49		USFS
35	Yes	1 of 3 clustered sites on USFS. Moderate. Discontinue 2 of 3.
48		USFS, moderate
12		USFS, slow
13	Yes	Steep, sandy, eroding site, but surveyor traffic may cause more erosion than what would otherwise occur, confounding the measurement. Private, high, rate of erosion determined.
36	Yes	This site likely will be lost as dock construction disturbs it.
14	Yes	Blueslide Resort. Actively eroding, moderate. Project share and rate of erosion determined.
15		Washington State downstream from Ruby. Actively eroding.
28		USFS, Ruby.
16		USFS, Panhandle.
17		USFS, Panhandle.
18		USFS
19	Yes	KIR. Very gentle slope. Aquatic weeds confound measurements.
57		KIR, actively eroding.
20T		KIR, treated/control pair.
20C		KIR, treated/control pair.
56		KIR, eroding.
55		KIR, eroding.
54	Yes	KIR, mapped moderate, but little erosion has occurred in past few years at the site.
52		PowWow Grounds site.
53		Calispell Creek site.
39	Yes	District, slow.
51		KIR
22		Washington state. Slow.
37		USFS Pioneer, slow.
23	Yes	Private, high, rate of erosion determined, and landowner revoked permission to access.
24	Yes	Sandy Island with little to no erosion.
25	Yes	Upstream from Newport; little to no erosion.
26	Yes	Upstream from Newport; little to no erosion.

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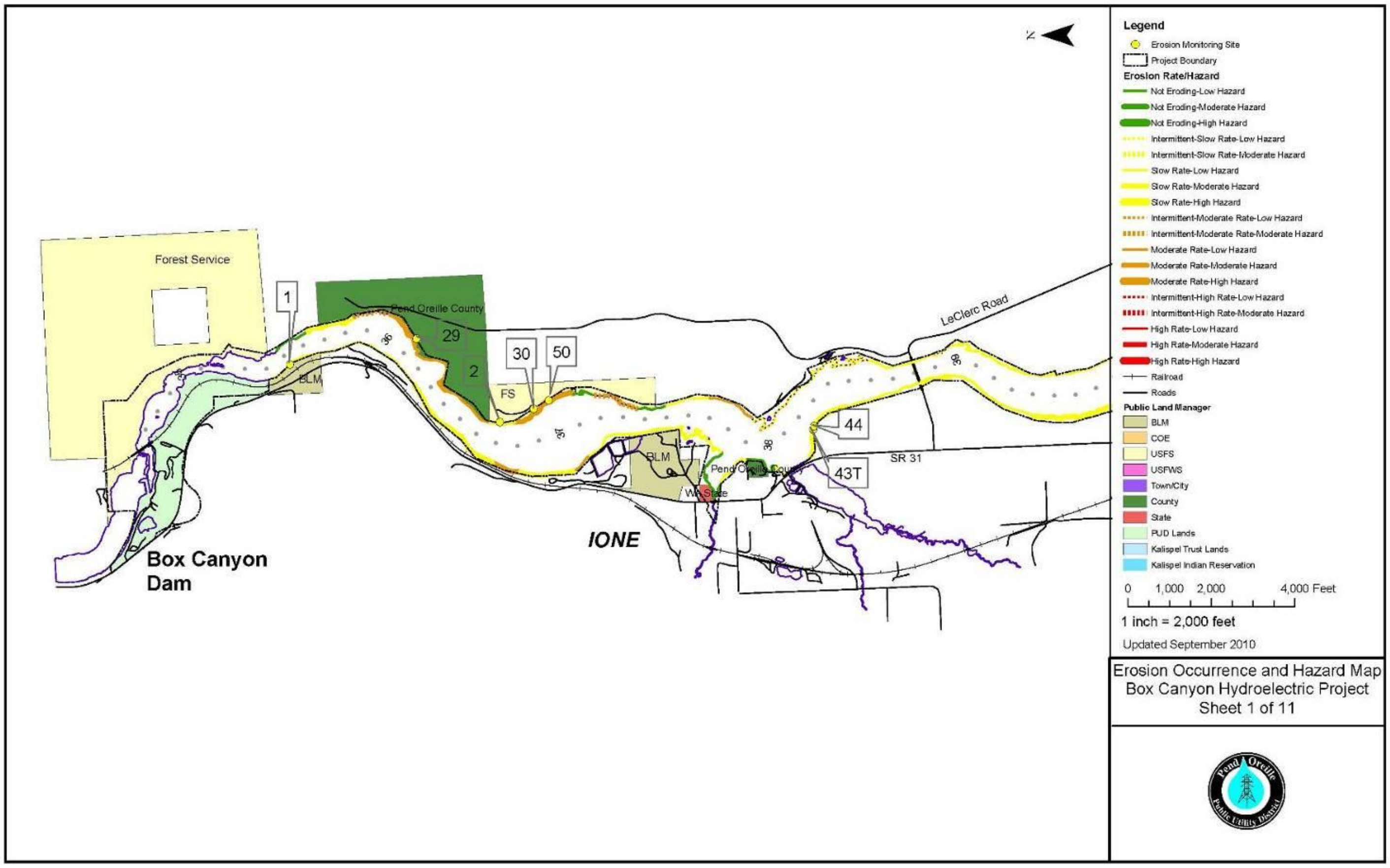
Appendix A. Shoreline Erosion Occurrence and Hazard Maps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Kalispel Indian Reservation
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1 inch = 2,000 feet
Updated September 2010
Erosion Occurrence and Hazard Map
Box Canyon Hydroelectric Project
Sheet 1 of 11
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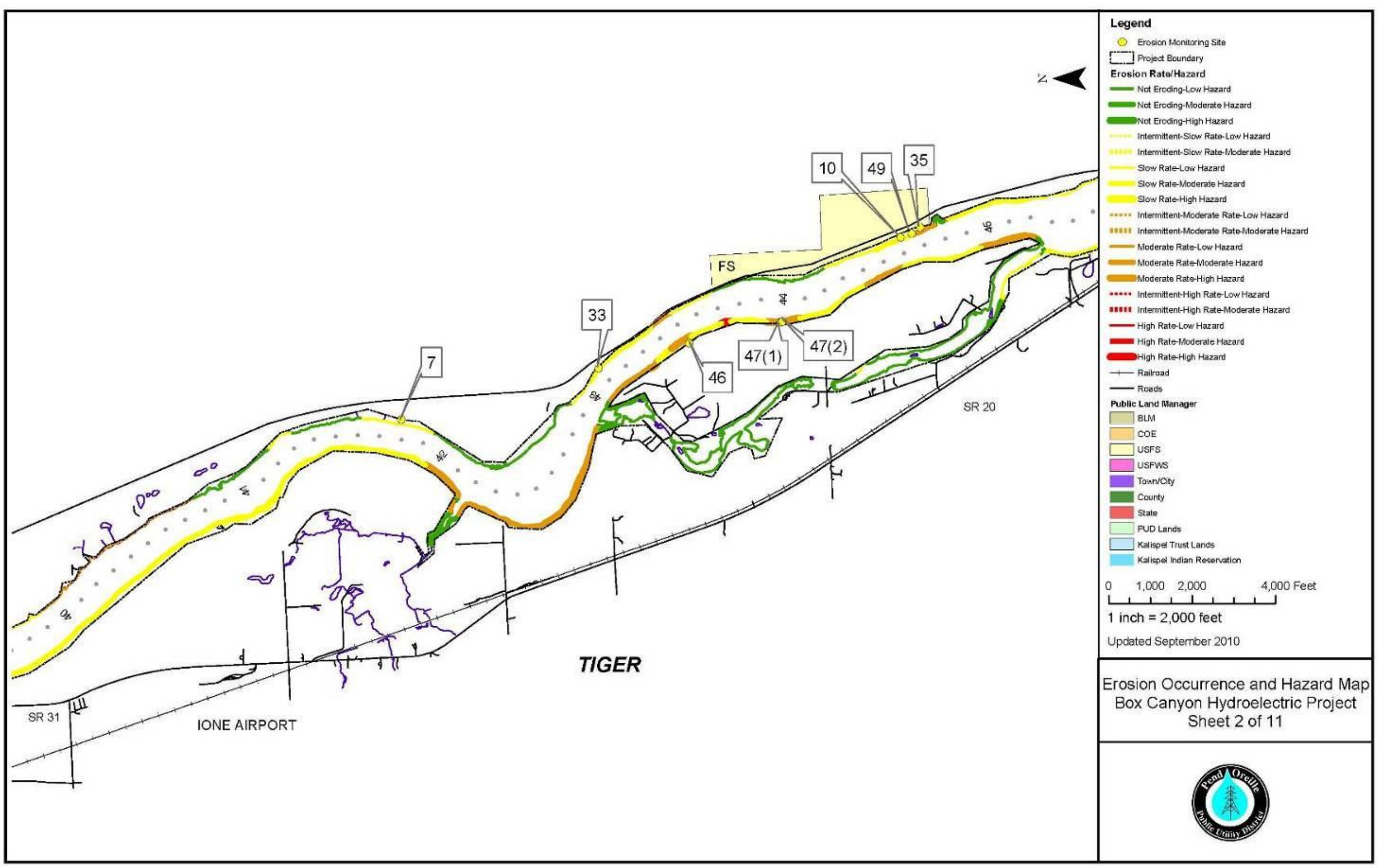
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1 inch = 2,000 feet
Updated September 2010
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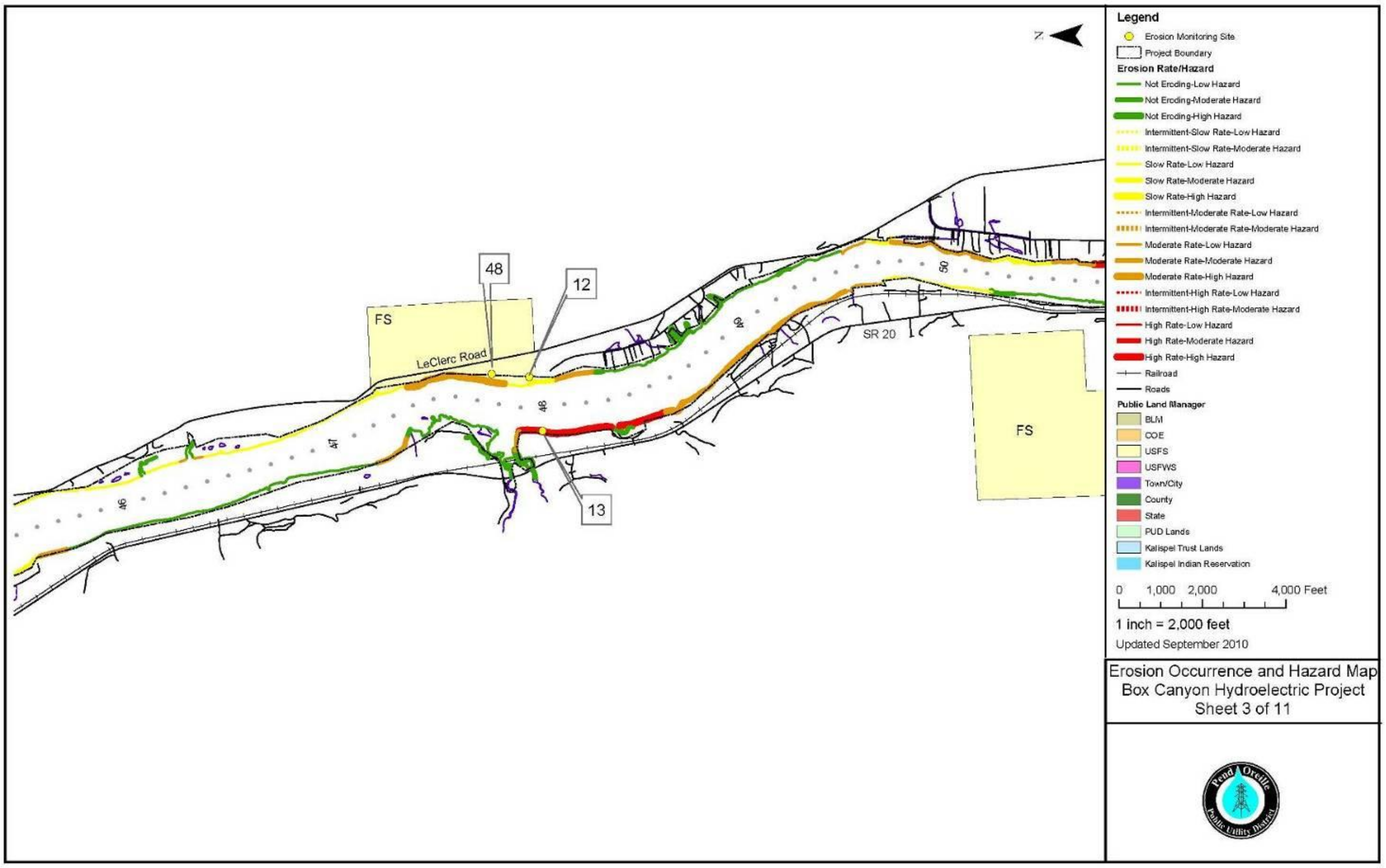
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1 inch = 2,000 feet
Updated September 2010
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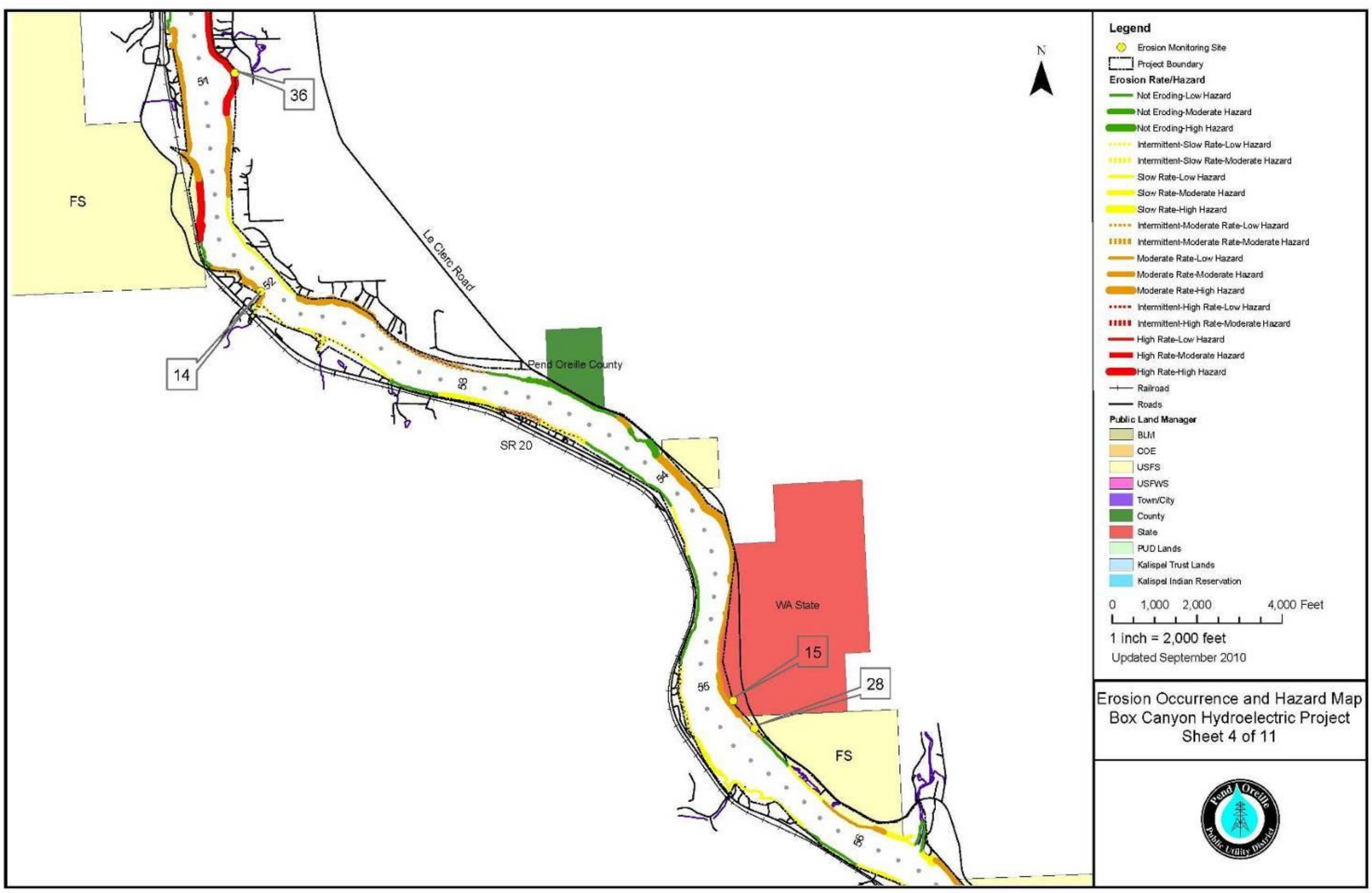
Erosion Occurrence and Hazard Map
Box Canyon Hydroelectric Project
Sheet 3 of 11
Pend Oreille
Public Utility District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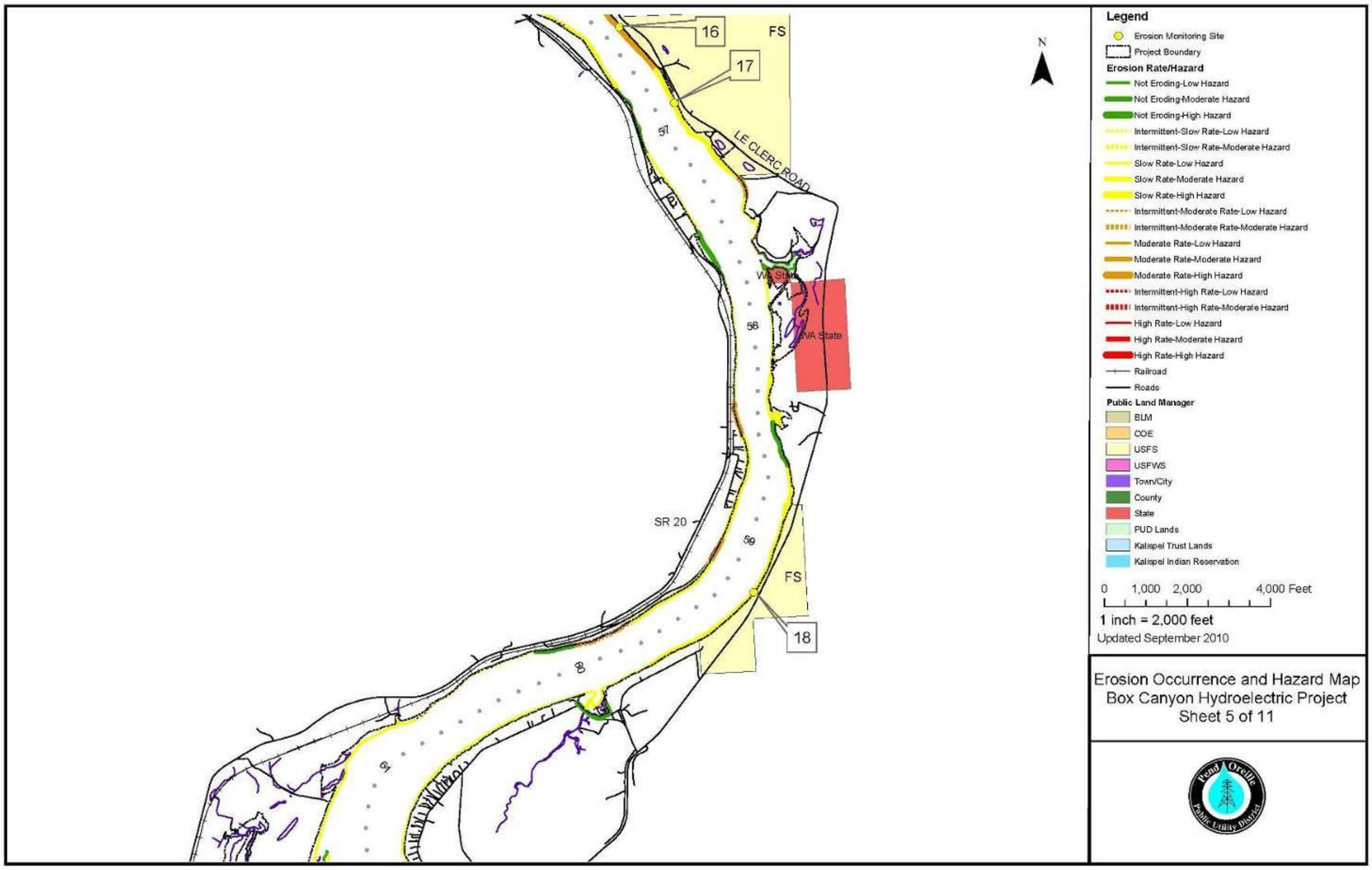
Box Canyon Hydroelectric Project
Sheet 4 of 11
Pend Oreille
Public Utility District



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Updated September 2010
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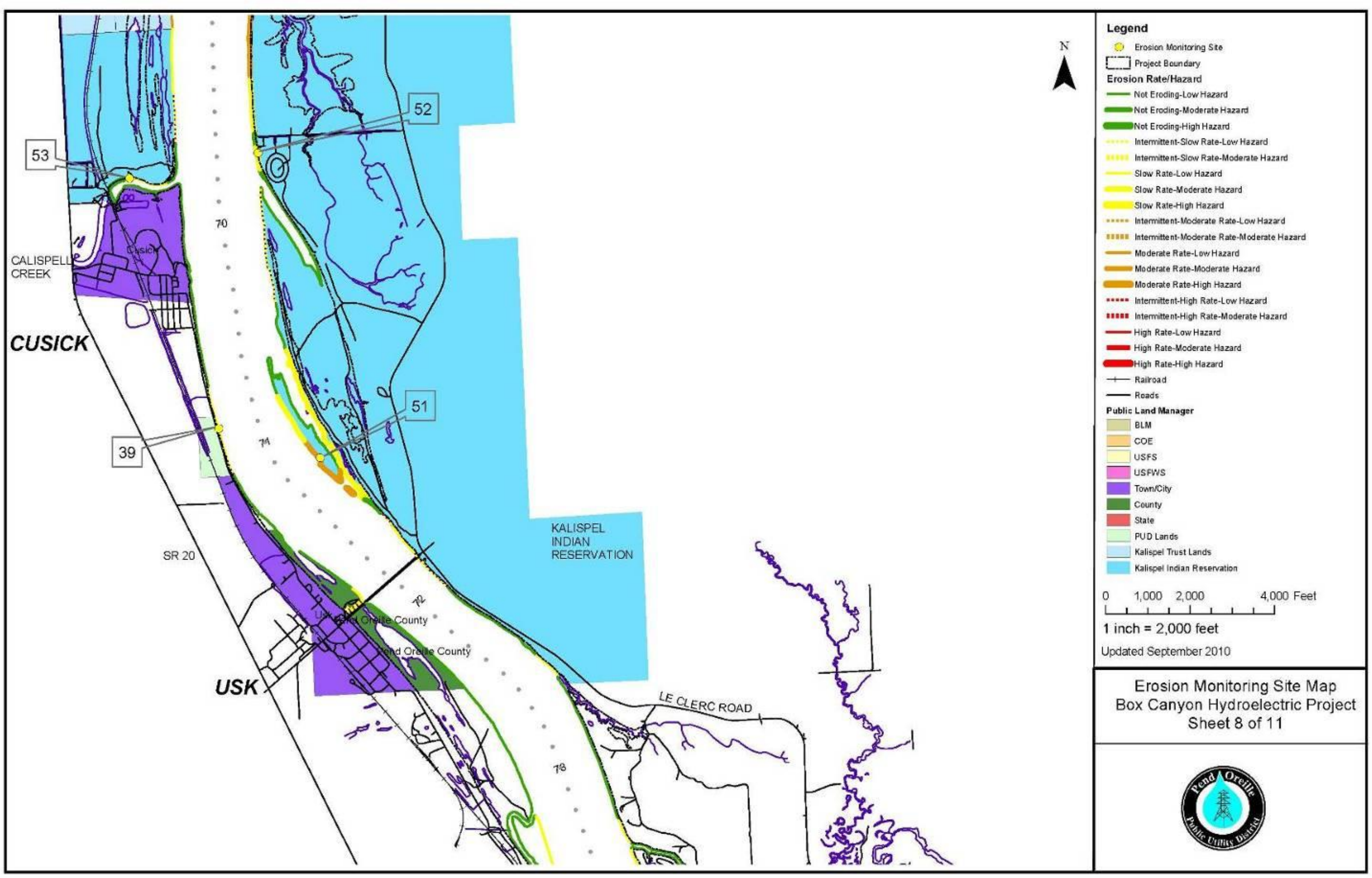
Box Canyon Hydroelectric Project
Sheet 5 of 11



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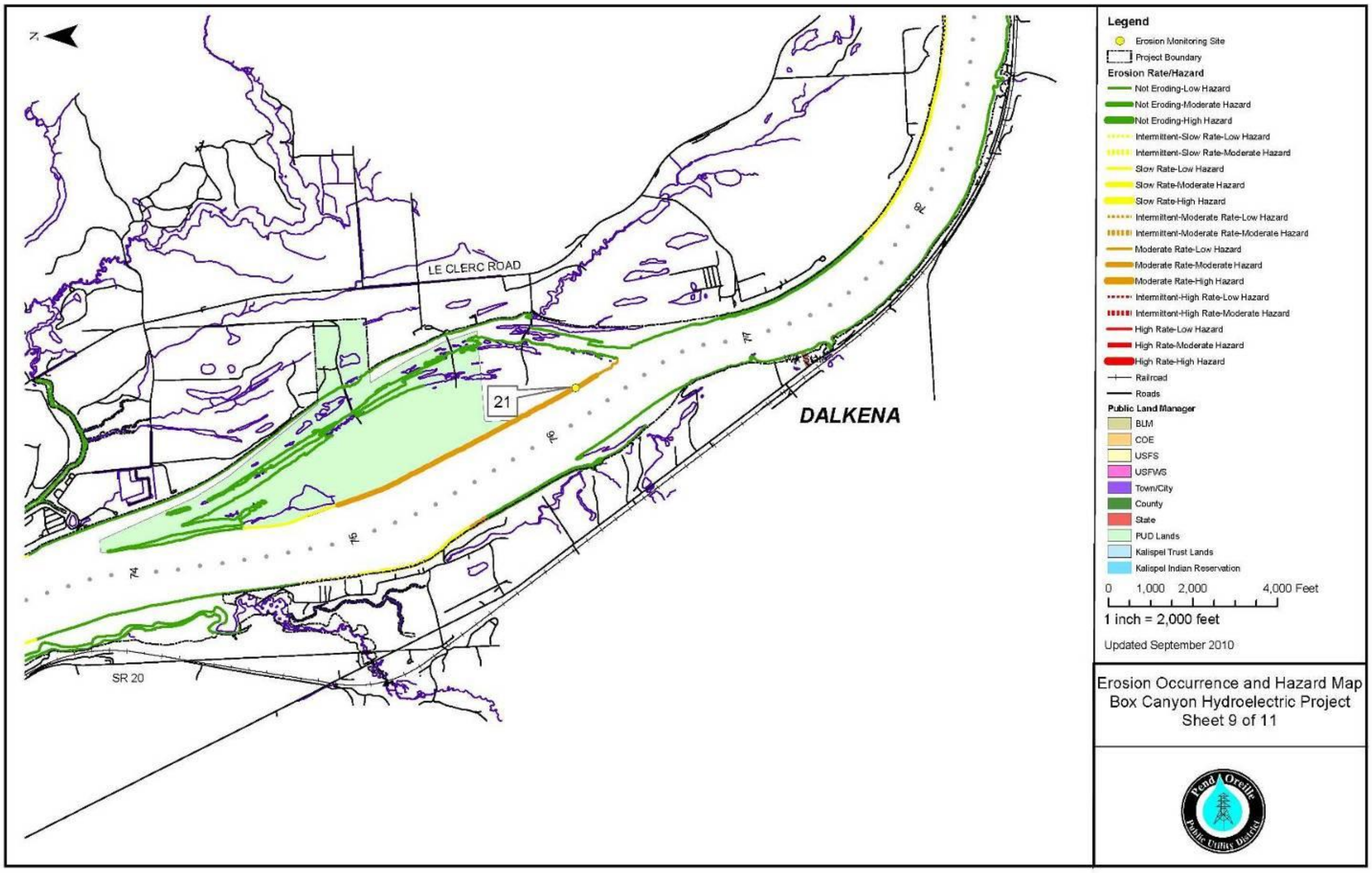
Erosion Monitoring Site Map
Box Canyon Hydroelectric Project
Sheet 8 of 11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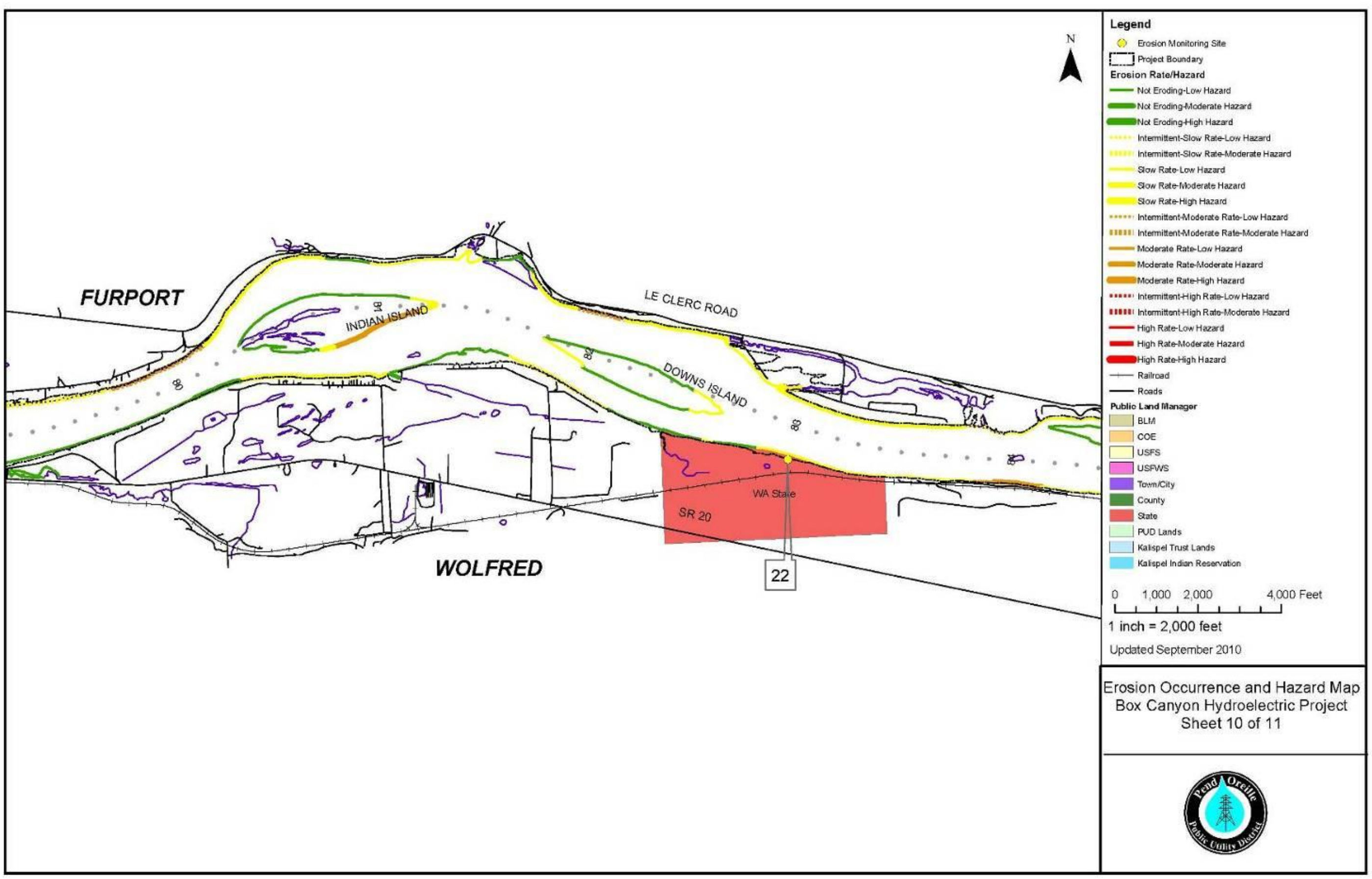
Erosion Occurrence and Hazard Map
Box Canyon Hydroelectric Project
Sheet 9 of 11
Pend Oreille Public Utility District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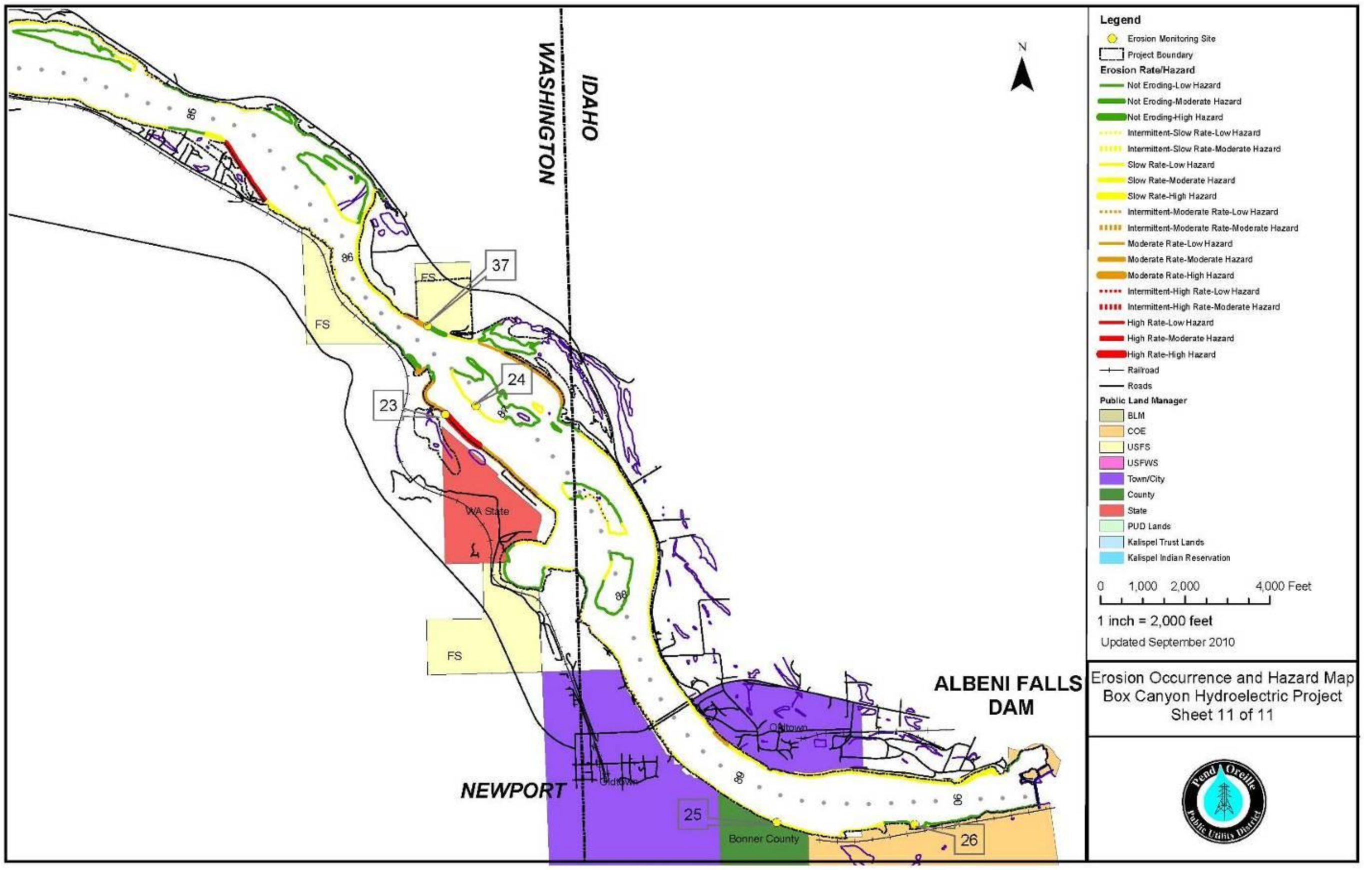
Erosion Occurrence and Hazard Map
Box Canyon Hydroelectric Project
Sheet 10 of 11
Pend Oreille Public Utility District



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1 inch = 2,000 feet
Updated September 2010
Erosion Occurrence and Hazard Map
Box Canyon Hydroelectric Project
Sheet 11 of 11

Appendix B.   Data Analysis Summary

Appendix B, Table 1. Total net erosion since inception of monitoring, and average annual rate of erosion at each monitoring site (depth in feet averaged across shoreline profile) through fall, 2010

Site	Net Total Erosion[8]	Average Annual Rate
1	-0.09	-0.01
29	0.27	0.03
2[9]	-0.26	-0.04
30*	-0.16	-0.02
50*	-0.17	-0.06
43T	0.02	0.00
44	-0.01	0.00
7	-0.07	-0.01
33	-0.12	-0.02
46	-0.09	-0.01
10	-0.17	-0.02
49	-0.17	-0.02
35	-0.20	-0.02
48	-0.10	-0.02
12	-0.16	-0.02
13	-0.60	-0.09
36	-0.37	-0.05
14	-0.08	-0.01
15	-0.36	-0.05
28	-0.61	-0.08
16	-0.27	-0.03
17	-0.33	-0.04
18	-0.33	-0.04
19	-0.14	-0.02
57	-0.61	-0.20
20T	-0.52	-0.06
20C	-0.71	-0.09
56	-0.07	-0.02
55	-0.10	-0.03
54	-0.19	-0.06
52	-0.16	-0.05
53	-0.20	-0.07
39	-0.38	-0.05
51	-0.07	-0.02
21	--	-0.04
22	-0.52	-0.06
37	-0.33	-0.04
23	-0.67	-0.08
24	0.01	0.00
25	-0.11	-0.01
26	-0.04	-0.01

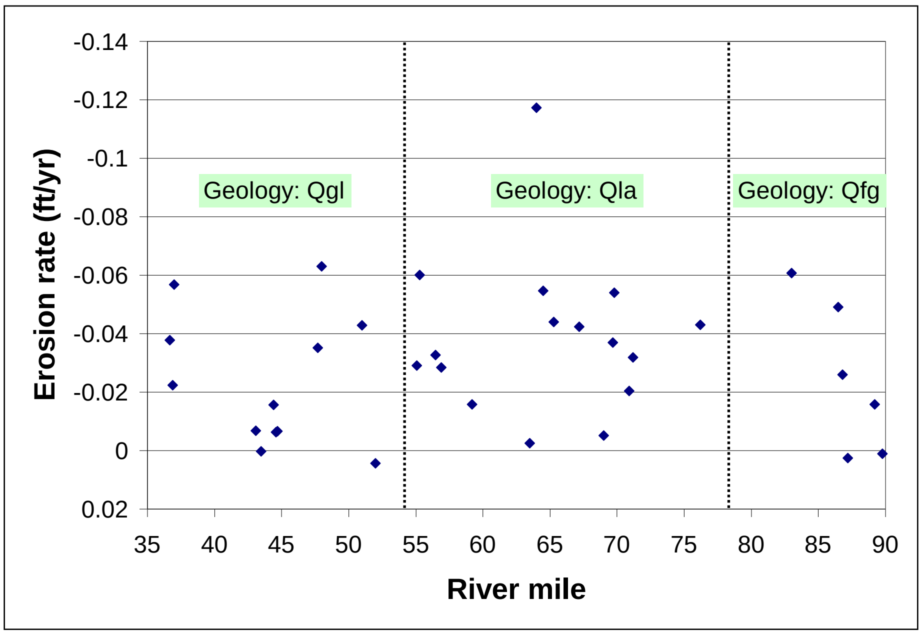
[8] Net total erosion and average annual rate of erosion are based on the number of years monitored at each site, varying from 7 years (most sites), to as few as two years for the most recently installed monitoring sites. Negative numbers indicate net erosion.
[9] Erosion rates reported for sites 2, 30, and 50 are through 2009 only. Although monitored during 2010, comparison of post- to pre-construction profiles is not valid.

Appendix B, Table 2. Sites with measurable bank recession (horizontal feet), summer 2007 through summer 2010

River mile	Site	Site Average	Annual rate (ft./yr.)
55.1 R	15	1.77	0.59
56.3R	28	0.57	0.19
64.0R	57	0.67	0.22
67.2R	55	1.00	0.33
83.0R	22	0.81	0.27
86.8R	23	1.10	0.37

Figure 1 illustrates that erosion rates do not vary systematically with river mile along the reservoir, or with surficial geology.[10] Reservoir elevation above natural and maximum variation in pool elevation through the year do vary systematically through the reservoir by river mile, but given that erosion rates do not, it follows that they also do not vary in relation to pool elevation and extent of pool variation. Absence of correlation of rates to geologic type likely is because nearly the entirety of the shoreline was formed by glacial, alluvial deposition – young and erodible materials. Note that in all of the following figures, monitoring sites that have been treated with erosion control measures, and sites located on landslides have been excluded from the analysis; treatment obscures relationship of erosion rate to natural circumstances, and landslides are dominated by landslide process, not characteristics such as vegetative density, presence of waves, slope, etc.

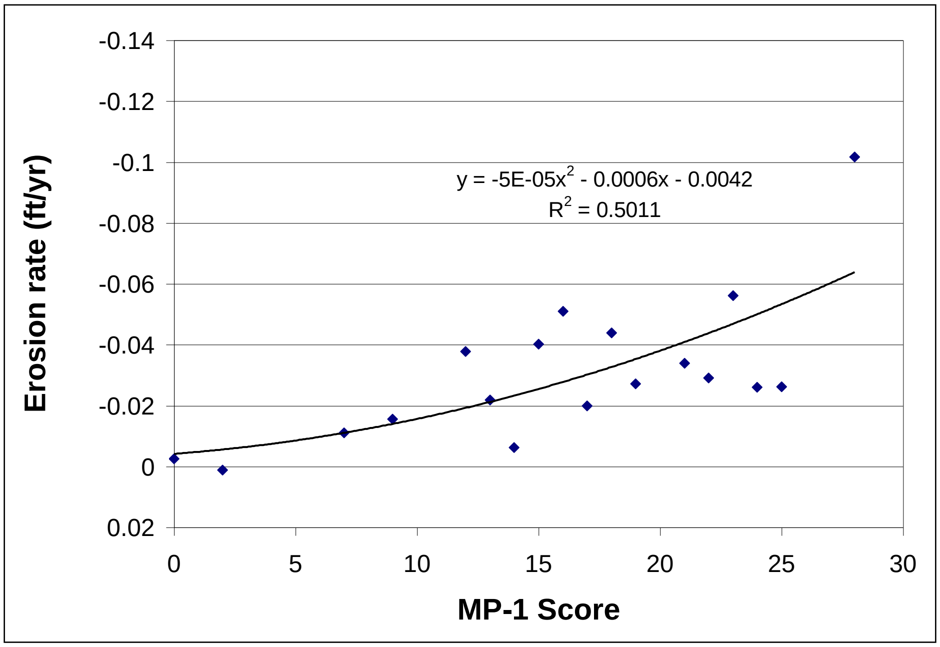
Appendix B, Figure 1. Rates of erosion in relation to surficial geology



[10] The figures and analysis for this discussion is based on erosion data through 2009. analysis through 2010 is pending, but preliminary review of 2010 erosion rates reveals that the relationships presented here would change very little with the additional year of data.

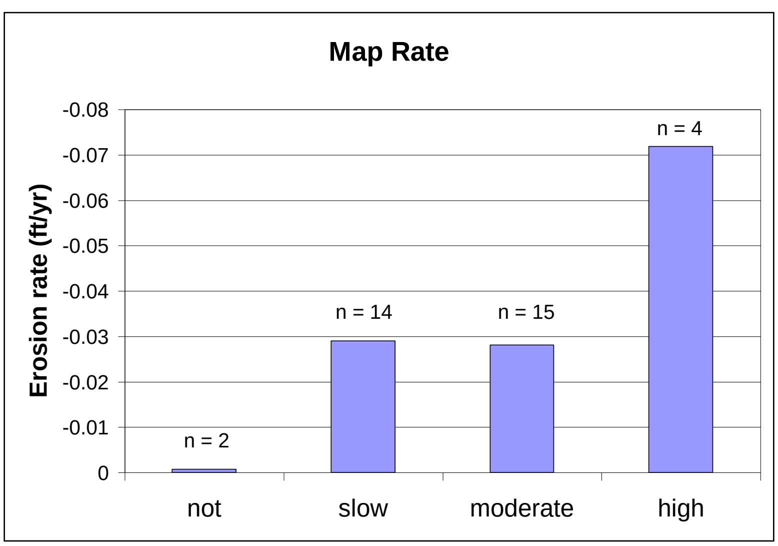
Figure 2 illustrates that the MP-1 erosion rate/severity process ratings are related to measured rates of Box Canyon Reservoir shoreline erosion, and are therefore useful for mapping estimated severity of shoreline erosion throughout the reservoir.

Appendix B, Figure 2. Rates of erosion in relation to MP-1 erosion rate/severity process ratings



Strong relationship of measured rates of erosion to mapped rates of erosion for the reservoir shorelines is also demonstrated by Figure 3.

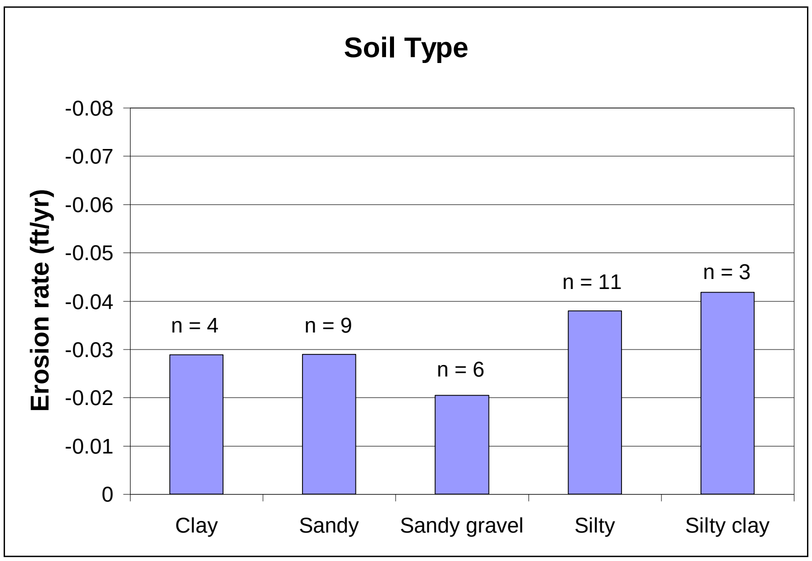
Appendix B, Figure 3. Monitored rate of shoreline erosion in relation to mapped rate



Relation of erosion rate through 2009 to individual shoreline characteristics was also examined. Collectively, these relationships illustrate that no single site characteristic consistently indicates rate of erosion (severity) at the monitoring sites, and by inference, throughout the reservoir.

Figure 4 illustrates erosion rates in relation to soils as represented by soil texture. For this examination we applied soil texture of the shoreline profile found at the relatively high seasonal flow of 70kcfs where shorelines usually are most steep and that typically are most subject to erosion as evidenced by the succession of profiles through time (see 2010 annual shoreline erosion monitoring report). Figure 4 illustrates that while erosion occurs on all soil textures (nearly the entirety of Box Canyon Reservoir shorelines are composed of unconsolidated alluvial deposits), silty soils, on average, seem to experience more rapid rates of erosion than either sandy or clay soils, and that presence of gravel within soils further reduces rate of erosion.

Appendix B, Figure 4. Monitored rate of shoreline erosion in relation to soil texture



Figures illustrating erosion rate in relation to MP-1 index ratings for indicators of erosion rate and severity follow. Erosion rate in relation to the MP-1 rating for slope is shown in Figure 5, illustrating that steep-sloped profiles experience substantially faster rates of erosion than gentle-sloped profiles.

Appendix B, Figure 5. Erosion rates in relation to MP-1 slope steepness rating

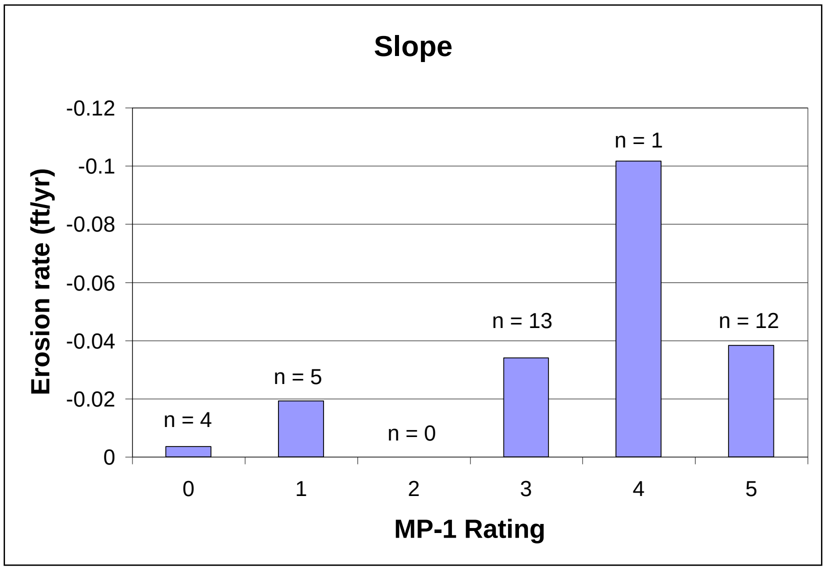


Figure 6 shows that rate of erosion is only weakly related to percent of bank surface covered by vegetation as rated through the MP-1 process. However, the relationship does demonstrate that the well-vegetated sites experience only very low rates of erosion. Our interpretation of this result is that while vegetative surfaces erode little, erosion rate of shorelines is dominated by that part of the shoreline profile that is not vegetated.

Appendix B, Figure 6. Erosion rate in relation to MP-1 rating for density of vegetation

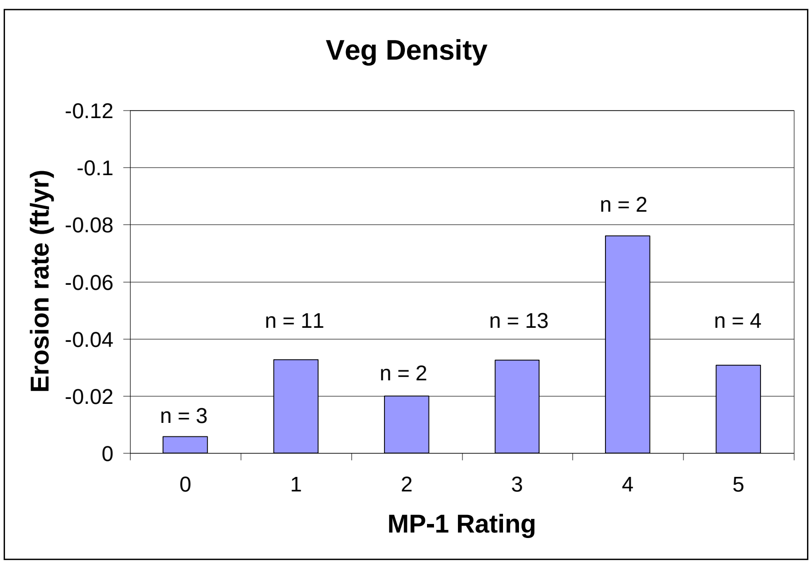
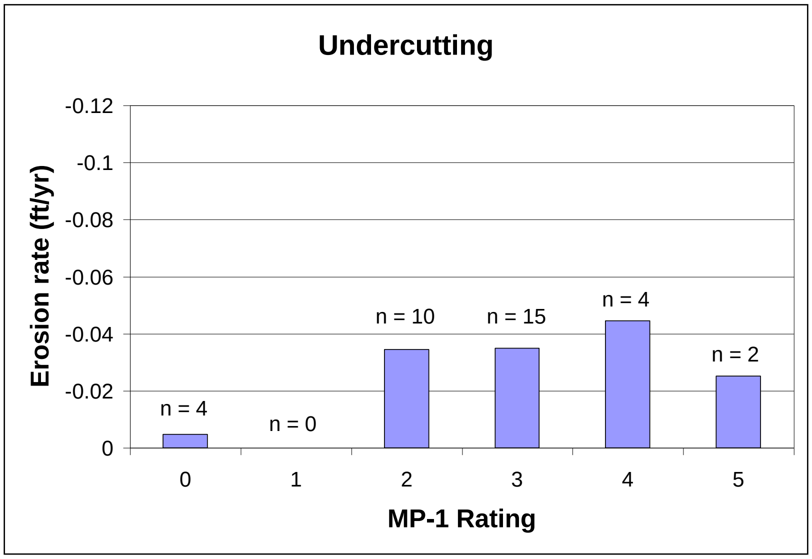


Figure 7 indicates that wherever undercutting is observed, shorelines are likely eroding, but it does not reveal a strong relationship of the MP-1 rating to rate of erosion. In contrast, Figure 8 demonstrates a strong relationship of erosion rate to presence of terracing. Terracing in this context is the presence of wave or current-cut steps on the shoreline profile.

Appendix B, Figure 7. Erosion rate in relation to MP-1 rating for undercutting



Appendix B, Figure 8. Erosion rate in relation to MP-1 rating for terracing

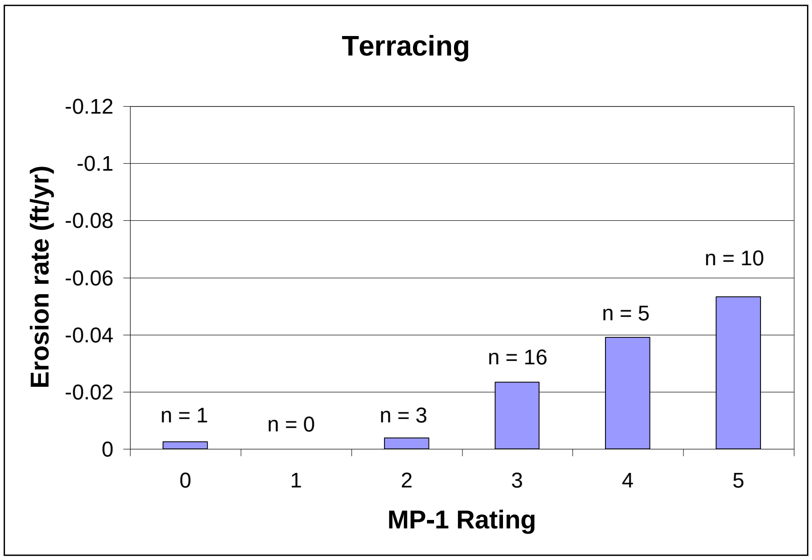
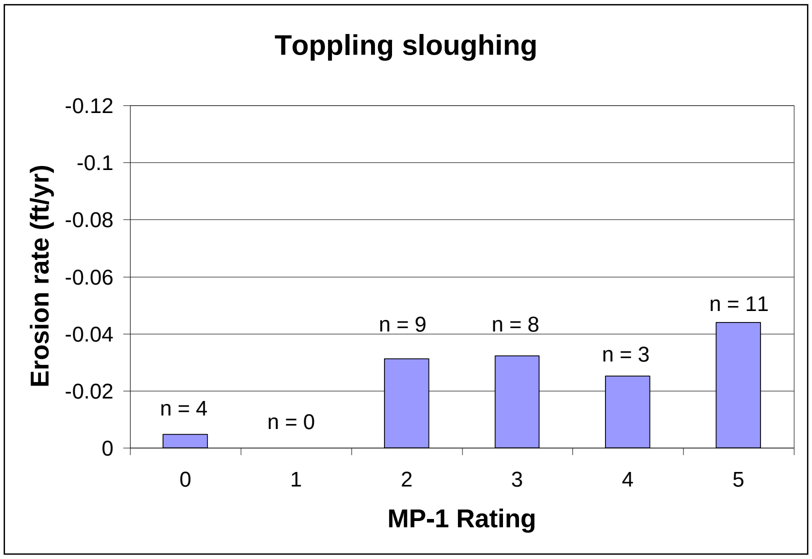


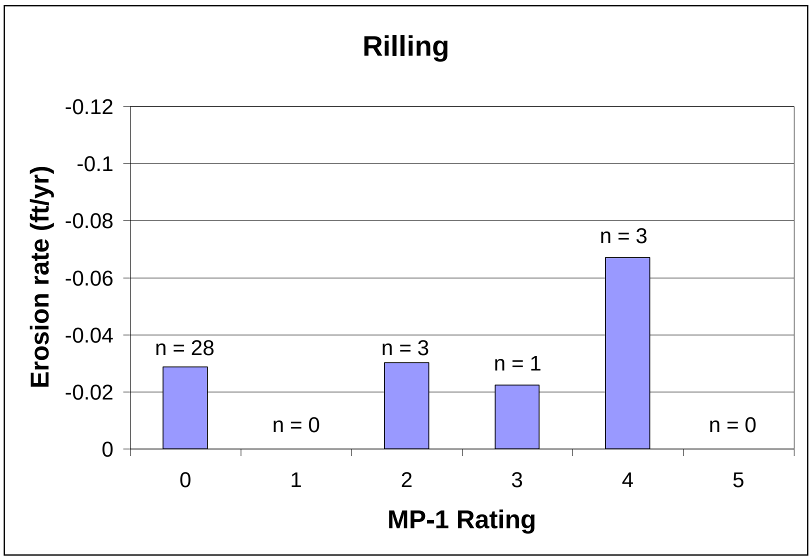
Figure 9 shows the relationship between measured erosion rates and bank toppling and sloughing, the end result that eventually follows undercutting. Undercutting and bank toppling and sloughing are common on Box Canyon Reservoir shorelines, and are associated with the highest rates of erosion observed.

Appendix B, Figure 9. Erosion rate in relation to MP-1 rating for toppling and sloughing

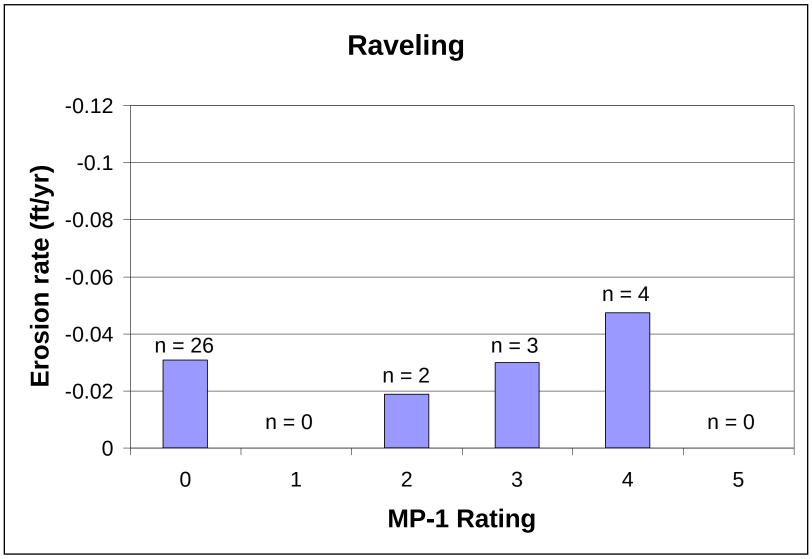


Rilling and raveling processes are also evaluated through the MP-1 process. Rilling at sites along Box Canyon Reservoir is most commonly observed on long, steep, sandy slopes, and is severe in some areas. Raveling also occurs on dry, sandy slopes, but like rilling, is not common. High MP-1 scores for both rilling and raveling are associated with high rates of shoreline erosion.

Appendix B, Figure 10. Erosion rate in relation to MP-1 rating for rilling



Appendix B, Figure 11. Erosion rate in relation to MP-1 rating for raveling

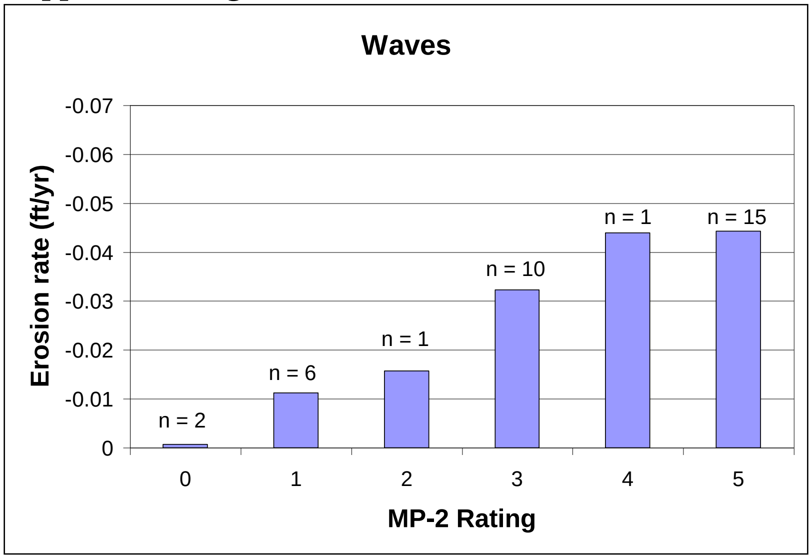


Recognizing that several erosion processes often occur simultaneously at a given location making it impossible to quantify the amount of erosion that any one process contributes to total bank erosion, the MP-2 rating process evaluates four potential causes of erosion: waves, current, groundwater, and trampling. Figure 12 indicates that presence of wave cut terraces are correlated with rate of erosion. Wave-cut terraces at multiple water levels are obvious along most Box Canyon Reservoir shorelines where erosion is occurring.

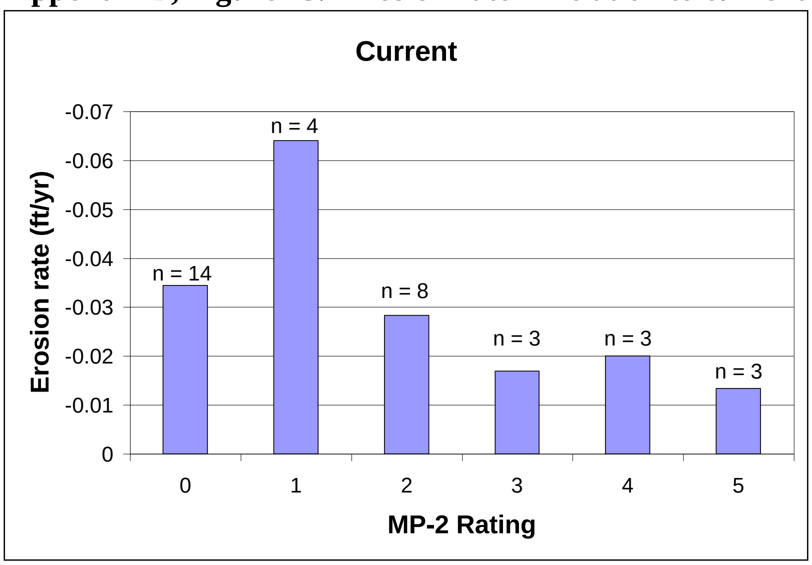
Figure 13 indicates that rate of erosion is poorly associated with current velocity along Box Canyon Reservoir shorelines. WDFW (2007, page 11) reports that "the forces of scour, even at extreme flows in the river, are very small; shear stress does not exceed 0.2 lbs/ft^2. As such, local scour along the banks of the Pend Oreille River within the reservoir can be considered relatively insignificant." However, current has been observed adjacent to some shoreline areas at high water levels and may be associated with the higher rates of erosion observed in 2008 during and following that years seasonal peak flows.[11]

[11] Peak flow in 208 reached 101,000 cfs, approximately the 3-year recurrence interval (i.e., the "3-year flood"), and the highest flows that have occurred since the District began monitoring under the Shoreline Erosion Monitoring Plan.

Appendix B, Figure 12. Erosion rate in relation to waves



Appendix B, Figure 13. Erosion rate in relation to current

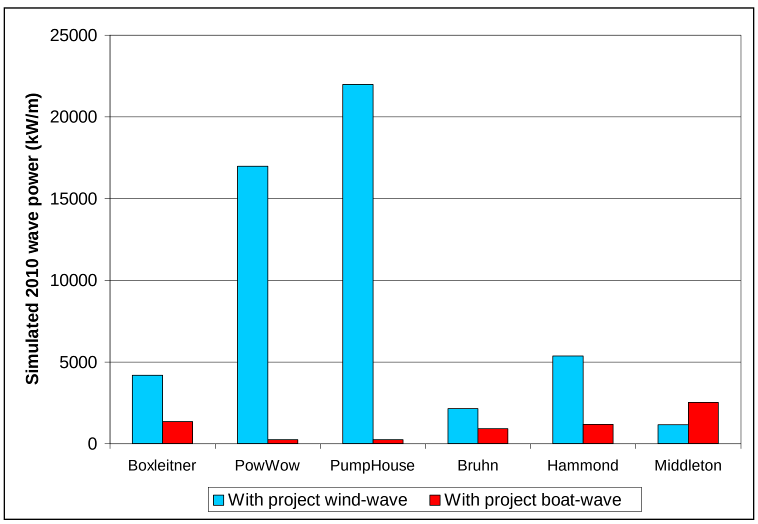


Waves are most often cited as the primary cause of shoreline erosion (Lawson, 1985; Riedel 1990; Saint-Laurent et al., 2001). Wind-formed waves are generally cited as the single most important cause of shoreline erosion (Gatto and Doe, 1993). Waves created by boats can also be important sources of shoreline erosion (Dorava and Moore, 1997; Klingeman and Cordes, 1993), and can equal or exceed those of wind waves. Per Project license requirements, the District was required to study the Project's effects upon waves and associated erosion. Accordingly, the District monitored wind, wind-generated waves, and boat-generated waves at 6 sites distributed along the reservoir's shorelines. From these data, the District simulated the wave power attributable to wind and boat waves incident to reservoir shorelines for both the existing "with project" (existing reservoir) and "without project" (riverine) circumstances (McGreer et al., 2010).

Wave power, expressed as Watts per meter of shoreline (W/m), increases with the square of wave height. Wave height has been found to increase with the 0.5 power of fetch distance (meters). However, with-project fetch distance increases at the 6 sites were found to be limited, varying from 37m (Boxleitner RM 79.9) to 86m (Pumphouse, RM 63.5). Simulated total annual wind-wave power per meter of shoreline (kW/m) increased from 3.0 percent (Pumphouse) to 9.4 percent (Hammond, RM 43.1) due to increased fetch with the project.

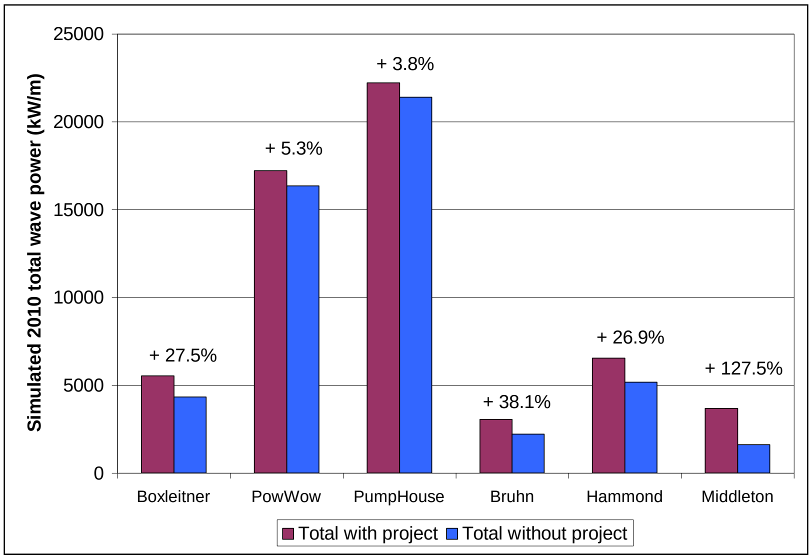
Boat-wave power was simulated using with- and without-project boat use information developed both from observation at the 6 monitoring sites and License application data. Boat use was estimated to have increased by 361 percent for the with-project scenario. Total pre-project boat-wave power varied dramatically: 51 kW/m at the Pumphouse and PowWow sites; 524 kW/m at the Middleton (RM 38.2) site. With-project boat-wave power (increased by 361 percent) remained negligible at the Pumphouse and PowWow (RM 69.8) sites in relation to wind-wave power, became substantial at the Boxleitner, Bruhn, and Hammond sites, and dominant at the Middleton site (Figure 14).

Appendix B, Figure 14. With-project wind and boat wave power



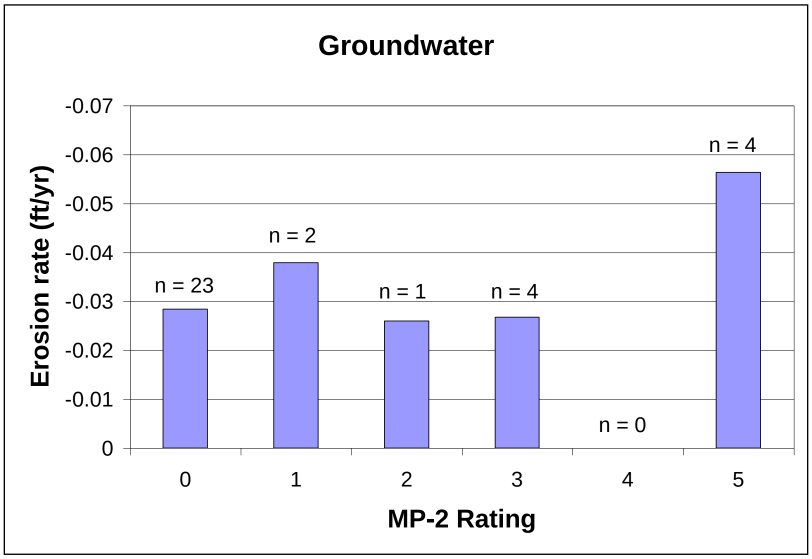
Total annual combined wind- and boat-wave power increases due to the project (with-project), expressed as a percentage, were found to be lowest at the Pumphouse and PowWow sites (4 and 5 percent, respectively) where increases in wave power are due primarily to increased wind-wave fetch distance; they are highest (127.5%) at the Middleton site where boat waves are dominant within this narrow section of river (Figure 15).

Appendix B, Figure 15. With- and without-project wave power



Groundwater as a cause of shoreline erosion was also examined (McGreer and Schult, 2010). Figure 16 shows the relationship between measured erosion rates and groundwater emergence from riverbanks at the monitored sites. Groundwater emergence likely occurs to some degree along many – perhaps most – shoreline areas. However, surface or subsurface groundwater emergence is most commonly associated with rapidly falling flows and river stage during the spring, and during periods when soils are wet from surface waters and rainfall. As a result, observations regarding presence of groundwater emergence are difficult to make, and are imprecise. Nevertheless, high rates of erosion are associated with high MP-1 ratings (Figure 16). Additionally, WDFW (2007) reports that subsurface flow due to positive pore pressure from groundwater along Box Canyon shorelines during falling river water levels causes small bank failures and undermining (undercutting) where areas of saturated soil liquefy and fail.

Appendix B, Figure 16. Erosion rate in relation to groundwater



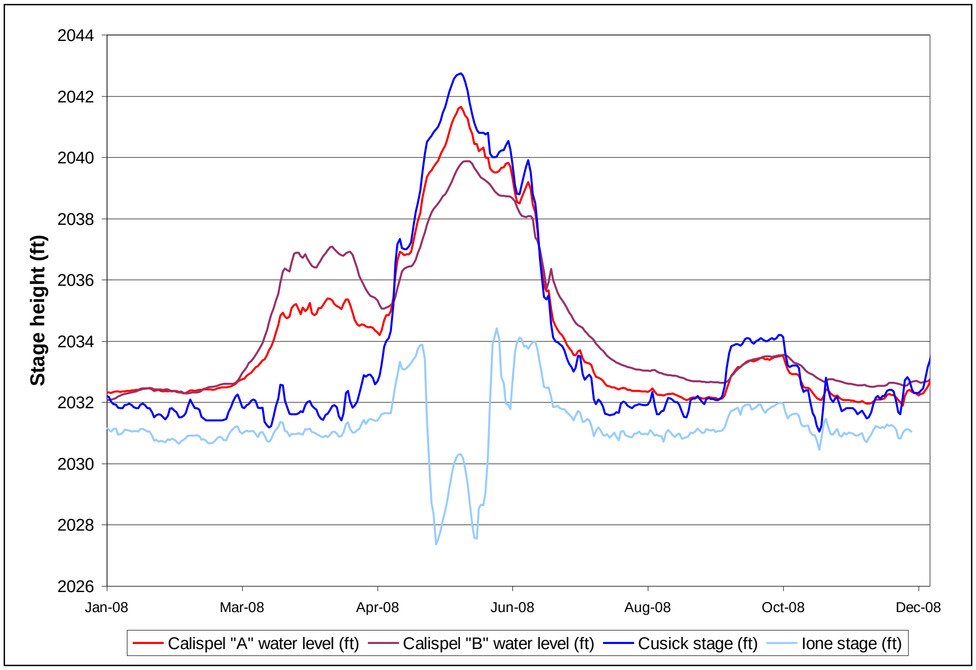
The District studied reservoir effects upon groundwater and soil stability in relation to drawdown within the Cusick Basin area, finding that drawdown at Box Canyon Dam associated with normal (non-emergency) operation does not affect river stage or groundwater elevations within the Basin (McGreer and Schult, 2010). This is illustrated by Figure 17 which shows groundwater relationships for the pair of wells at RM 69.8L in relationship to river stage nearby at Cusick (RM 70). Similar relationships were recorded at the two other monitoring well sites.

Figure 17 shows that in March, 2008, groundwater levels rose dramatically and independently from river flow and stage, and began to drop prior to when river stage at both Cusick and Ione rose with spring peak flows. These increases and decreases likely occurred in response to surface water effects associated with spring snowmelt and rainfall, and subsequent drying. Most interesting is the relationship of groundwater levels in relationship to stage at Cusick and Ione during the period of peak flow. During this period, the gates at Box Canyon Dam began to open as flow exceeded 62,000 cfs, and became fully open as flow exceeded 90,000 cfs. Stage upstream at Ione dropped by approximately six feet over the course of several days. However, river stage at Cusick near this monitoring well site continued to rise as river flows increased, essentially unaffected by conditions at the Dam, and groundwater within the monitoring wells did not respond to the drop at Ione. Groundwater levels in monitoring well A (closest to the river) mirrored stage effects at Cusick, where stage is controlled by river flows, and not by operation of Box Canyon Dam.

Figure 17 also illustrates that the greatest groundwater gradient potentially affecting stability of streambanks (represented by the difference in elevation between monitoring well A and river stage) occurs during the early spring prior to peak flows, when river flows are relatively low, and also when groundwater levels have risen appreciably due to precipitation, melting snow, or groundwater from upland sources. Groundwater levels during these conditions are unaffected by the reservoir.

Appendix B, Figure 17. Groundwater at the Calispell Creek (RM 69.8L) monitoring wells in relation to stage at Ione (RM 37) and at Cusick (RM 70) during drawdown at Box Canyon Dam, 2008

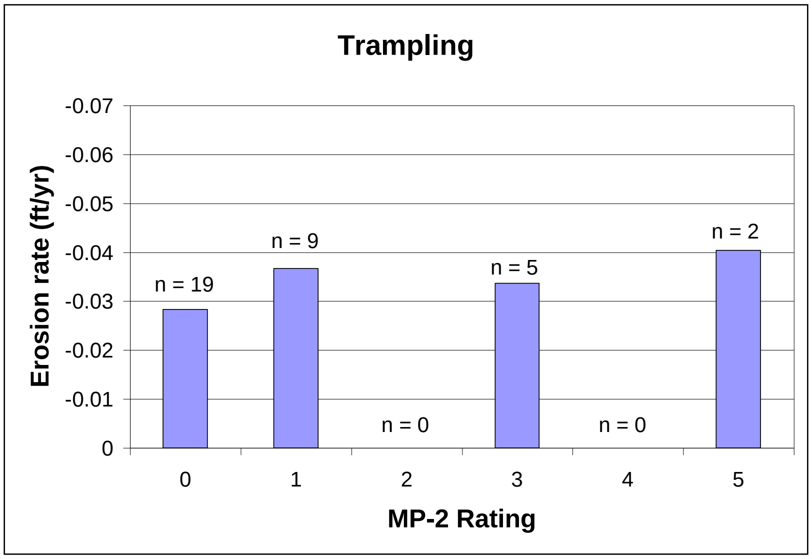
Monitoring well A is closest to the river.



Although these relationships demonstrate that normal operation of Box Canyon Dam does not cause drawdown of surface water elevations of the reservoir, emergency conditions could occur that would affect surface water and groundwater elevations in the Basin. The District examined potential (hypothetical) effects on bank stability by simulating sustained and rapid decrease in groundwater elevations at the three groundwater monitoring sites. Factors of safety of shoreline slopes at the most sensitive of the three Cusick Basin sites were found to decrease by as much as 18%.

Trampling of soil surfaces is notable in some areas and monitoring sites, but MP-1 ratings for trampling were not found to correlate well with rates of erosion (Figure 18).

Appendix B, Figure 18. Erosion rate in relation to trampling



Appendix C. Erosion Control, Prevention, and Remediation Plan
Field Tour, October 26, 2010
Project Scheduling Priorities for Initial Projects

WESTERN WATERSHED ANALYSTS
1339 Highland Ave.
Clarkston, WA 99403
(509) 758-3893 • FAX (509) 758-9469

December 6, 2010

To: Mark Cauchy
Re: Erosion Control, Prevention and Remediation Plan Field Tour, October 26, 2010

This memo's purpose is to provide a record of the Erosion Subcommittee's 'Erosion Control Project ID Team' general observations made during the Team's field tour on October 26 that culminated in a discussion and draft prioritization of erosion control projects on Tribe and National Forest ownerships. These notes should be considered draft and subject to additions and corrections from the ID team participants.

I clipped the following text from our draft ECPRP as a reminder of our purpose for the trip:

> As suggested at the June 14, 2010 Erosion Subcommittee meeting, an Erosion Control Project ID Team will be formed to review field circumstances and potential erosion control projects. The team will execute an evaluation process. The team will collectively visit and field-evaluate sites per an evaluation process, described below, in order to assess circumstances surrounding potential project sites. Potential sites will be suggested by members of the team in advance of an annual field tour so as to provide a discreet set of sites to be visited and assessed. Also as suggested at the June 14 meeting, the ID team will include representatives of six entities: the District, Tribe, Forest Service, WDFW, and WDOE. The District will facilitate and coordinate these field evaluations each year, will tally and communicate the results of the team's evaluations, and will provide the 5-year project schedule based on the team's priorities.
>
> For each site suggested by any member of the ID team, each member would consider and discuss with the Team the list of factors and other considerations that may apply to a site.

Representatives of each ID team agency were represented on the trip. Five sites were suggested as candidate projects and were visited; two Tribe projects and three Forest Service. Considerations discussed at each site included:

- Severity of erosion
- Causes of the erosion
- Values at risk and ability to improve those values
- Specific areas needing treatment
- Conceptual approach for effective control
- Practicability of timely design and permitting

Following is a summary of the group's discussions and consensus organized in order of the five sites visited.

Tribe dike site, RM68.9R - ~RM70.9R

Areas of moderately severe erosion interspersed with somewhat less severe areas occur throughout this approximately one mile of shoreline. The primary cause of erosion along the shoreline is waves combined with elevated reservoir waters. The area is immediately bordered by an earthen dike with road highly valued by the Tribe. The shoreline also has high riparian habitat value, and limited heritage values. The Tribe has addressed similar areas with good success using a combination of 'hard' (rock) and bioremediation, and selective placement or rock and extensive willow, dogwood, and other suitable species would likely be prescribed for this area. The group agreed that erosion control could be accomplished using these techniques with very high certainty of success. This project could likely be permitted and implemented beginning in 2011, although treatment of the entire area may extend through additional years, depending on the level of funding available per year.

USFS parcel #7, RM 58.8R – 59.4, Riverbend

The shoreline in this area is characterized by moderately high and moderately steep silty clay banks. Shorelines along the parcel appear to have generally adjusted to elevated reservoir levels through time since construction of Box Canyon Dam and have revegetated reasonably well; rate and severity of erosion is generally slow. However, two areas of limited length near the southern (upstream) end of the parcel near RM 59.4 are eroding more severely. A combination of waves, elevated reservoir waters, steep slopes, and groundwater emergence contribute to erosion at the locations. The Team agreed that these areas could be effectively treated by placing rock at the base of the steep slope (formed by wave cutting) coupled with planting with shrubs and grasses. Exact areas to treat and design will be determined once general agreements to proceed are reached. Values at risk for these areas are principally riparian habitat, which the group agreed could be effectively improved with the general treatment approach discussed.

USFS parcel #6, Panhandle Campground, RM 56.4R -57.3

Much of the Panhandle parcel is characterized by beached lower slopes with gentle gradient that are becoming increasingly well-vegetated with grass and shrubs. However, on the order of 1,000 to 2,000 feet of this area are eroding more rapidly. These areas are characterized by steep, sandy, easily eroded upper slopes, with poorly vegetated beached areas below. A combination of waves, elevated reservoir waters, and the steep sandy upper bank conditions contribute to erosion of these areas. Values along these areas are principally as habitat. Bioremediation of these areas principally through revegetation was discussed, but some Team members had reservations about bioremediation as a stand-alone approach given the sandy and highly erodible nature of the upper slopes; Some combination of rock placement at the toe of the steep slope coupled with aggressive revegetation treatments perhaps utilizing a vegetated geogrid approach with layers of compacted soil and gravel lifts alternated with live willow branch cuttings and shrub and grass planting of the lower slope beached areas may be needed. Exact areas to treat and a design will be determined once general agreements to proceed are reached.

USFS parcel #2, RM 43.7R – 44.7, Tiger

Shorelines along this parcel of Forest Service ownership are characterized by moderate gradient slopes with lacustrine silts overlying clayey sands with gravels and cobbles. Most of this shoreline experiences only slow rates of erosion as gently-sloped beaches with gravels and cobbles have developed and become revegetated with grasses and willows. However, waves combined with elevated reservoir waters contribute to undercutting and oversteepening of upper bank slopes and moderate severity of erosion in some areas near the southern (upstream) portion of the parcel. Similar to the Panhandle site, bioremediation of problem upper slope areas with a vegetated geogrid approach using layers of compacted soil and gravel lifts alternated with live willow branch cuttings and shrub and grass planting of the lower slope beached areas likely would allow these slopes to vegetate and stabilize. Values at risk for these areas are principally riparian habitat.

Tribe Trimble-Scheibel parcel, ~ RM 67

Approximately one mile of this shoreline is eroding at moderate rates primarily due to waves combined with elevated reservoir waters and a history of streambank grazing which has recently been eliminated. The area has high riparian habitat value and limited heritage values. Erosion of the area could be effectively treated by placing rock at the base of the steep slope (formed by wave cutting) coupled with planting with shrubs and grasses.

Project Ranking / Priority

The Team met at the end of the field day to further discuss the sites visited, general observations, and to rank the 5 sites for scheduling priority. A draft project priority ranking form was used to help guide the evaluation. While helpful, opportunities to improve the form were noted. The Team universally agreed that the Tribe dike site was the highest priority for erosion control. Team consensus then was that Tribe Dike was followed by the FS Riverbend in a near tie for second place with the Trimble / Scheibel site. Panhandle was then generally ranked fourth with the Tiger site as fifth. Ray Entz noted that substantial heritage resources located approximately one mile upstream from tribal headquarters near RM 71R may be at risk to erosion and that the Tribe' priorities may shift to this area. Monitoring site 51 is located there and the information gathered at and near the site may be helpful for addressing this area.

APPENDIX D

BOX CANYON RESERVOIR GROUNDWATER AND BANK STABILITY MODELING

Prepared for

Public Utility District No. 1 of Pend Oreille County

by

Dale J. McGreer, P.G.
Western Watershed Analysts

And

Dennis T. Schult
EES Consulting

May 25, 2010

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INTRODUCTION

Pursuant to the Order Issuing New License issued July 11, 2005, and Department of the Interior 4(e) Condition 3.E in Appendix A for the Box Canyon Hydroelectric Project, Public Utility District No. 1 of Pend Oreille County (District) was required to develop a plan for conducting geotechnical engineering studies on the Kalispel Indian Reservation (KIR) to include:

- Accurate field surveys of the shoreline profile at eight erosion monitoring transects located on the KIR.
- Monitoring of shoreline embankment ground water elevations with respect to a fixed elevation reference to determine changes in the phreatic surface in response to reservoir level fluctuations.
- Incorporation of soil/site parameters into a quantitative slope stability model to determine how a drawdown rate limit of three inches per hour affects KIR shorelines.

On August 29, and supplemented on September 21, 2006, the District filed its Geotechnical Engineering Study Plan (Plan) with FERC. On September 29, 2006, FERC approved the Plan as filed. Key provisions of the Plan include:

- Coordinate with the Kalispel Tribe (Tribe) to field locate three groundwater monitoring sites along the KIR shoreline.
- At each of the three groundwater monitoring sites, bore two groundwater monitoring wells at varying distances from the bank.
- Collect core samples at each location for laboratory analysis of soil properties, and analyze soil parameters for modeling groundwater seepage and bank stability.
- Install groundwater level monitoring data loggers in the wells drilled at each site to record groundwater levels.
- Employ Geo-Slope International's SEEP/W or other similar model(s) to simulate the dissipation of excess pore water pressure for reservoir drawdown at a rate of three inches per hour, at natural rates of drawdown that may exceed three inches per hour, and for any operating excursions where drawdown exceeds three inches per hour.
- Employ suitable bank stability models to estimate the bank Factor of Safety (FOS) due to reservoir drawdown at a rate of three inches per hour at each of the three sites.
- Prepare a report summarizing soil characteristics and modeling results.

Article 403 of the license was amended in 2006 to require that the District shall not reduce the surface elevation of Box Canyon Reservoir by a rate that exceeds three inches per hour, as measured at Box Canyon Dam. Effective May 26, 2009, FERC amended Article 403 of the License, in part, to read: "The licensee, in an effort to minimize the fluctuation of the Box Canyon reservoir surface elevation, shall not reduce the surface elevation by a rate that exceeds three (3)-tenths of a foot (3.6 inches) within any one-hour period, with the exception being; when the Pend Oreille River flows are 60,000 cfs or greater, the rate of drawdown of the Box Canyon Reservoir water surface may not exceed nine (9)-tenths of a foot (l0.8 inches) within any 3-hour period, as measured at the USGS gage at Ione."

Per the Order of May 26, 2009, FERC also required that the licensee shall monitor for erosion annually during early spring and early fall and shall present their findings in the Annual Reports. If the licensee demonstrates to the Secretary of the Interior (Secretary) over this interim period that the rate of erosion is not affected by the amended drawdown limitations, then the amended drawdown limitations shall become standard practice beginning May 1, 2015, after receiving approval from the Secretary (FERC).

Pursuant to the Geotechnical Engineering Plan, the District and the Tribe field-located the three groundwater monitoring sites in the fall of 2006. Groundwater monitoring wells were installed and soil sample cores were obtained in 2007. The three locations on the KIR selected for installation of groundwater monitoring wells and for which bank stability was modeled are:

- PowWow Grounds near the boat launch (RM 69.7 right bank)
- Calispell Creek (RM 69.8 left bank)
- Flying Goose (RM 64.0 right bank)

GROUNDWATER CONDITIONS IN RELATION TO RIVER STAGE AND DRAWDOWN AT BOX CANYON DAM

The following text and Figures 1 through 4 are excerpted from the District's 2010 Annual Shoreline Erosion Monitoring Report. The relationships discussed have direct bearing on the potential for drawdown at Box Canyon Dam, and are therefore repeated in this report.

During rapidly increasing flow conditions in May 2008, drawdown events in excess of three inches per hour occurred at the gauge below Box Canyon Dam. The District's consulting geologist observed shoreline conditions throughout the reservoir prior to, during, and after peak flow conditions and following these drawdowns. A report dated December 4, 2008, regarding drawdown effects was prepared and was included as Appendix D to the 2008 annual monitoring report. In summary of the observations described in that report, little evidence of shoreline erosion could be attributed to drawdown during 2008. Within the Cusick Basin and along KIR shorelines, drawdown at Box Canyon Dam did not express itself upstream within the Cusick Basin.

Drawdown effects associated with normal operation of Box Canyon Dam during rising flow conditions such as those experienced in May 2008 are limited to that portion of the reservoir lying downstream from Ruby Ferry at RM 55. This was the case even though drawdown in excess of the 3 inch-per-hour limitation occurred twice during May 2008. This is evidenced by the Figure B2.4-1 Reservoir Water Surface Profiles vs. Flow Upstream of Box Canyon Dam that is part of the project license application. Figure B2.4-1 shows that as flows increase from 70,000 cfs towards 90,000 cfs (and as water surface elevations are "drawdown" per normal operating procedures at the dam), stage decreases between the dam upstream to the vicinity of Ruby Creek at RM 55.6, and that stage *increases* in these circumstances upstream from Ruby. This finding is supported by the river flow data, stage data recorded near Ione (RM 38), the stage data recorded near Cusick (RM 70) (Figure 1) and by the groundwater monitoring data (Figures 2, 3, and 4).

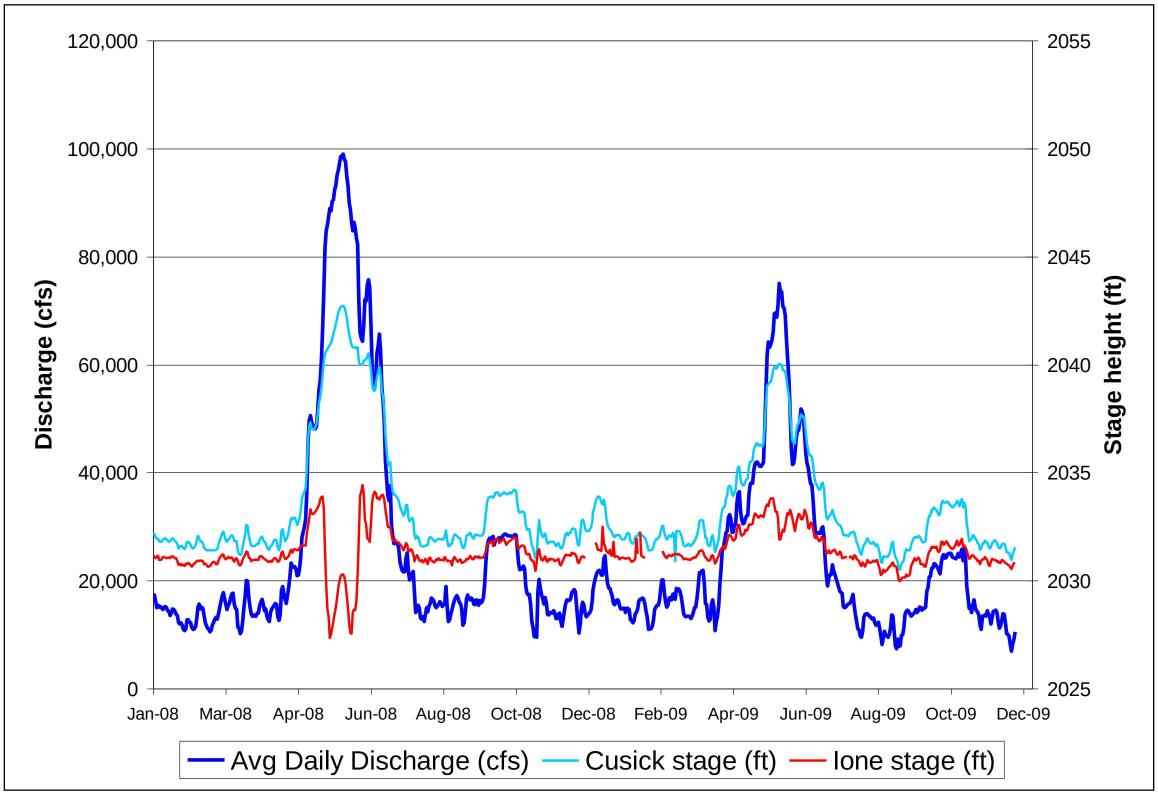

Figure 1. Pend Oreille River Flow Below Box Canyon Dam in Relation to River Stage at Ione and Cusick.

Figure 2 illustrates groundwater relationships for the pair of wells at RM 64.0 (Flying Goose) in relationship to river stage nearby at Cusick (RM 70) for 2008 when the Pend Oreille River peaked at over 100,000 cfs. Figure 2 shows that in March, 2008, groundwater levels rise dramatically and independently from river flow and stage, and begin to drop prior to when river stage at both Cusick and Ione rise with spring peak flows. These increases and decreases likely occur in response to surface water effects associated with spring snowmelt and rainfall, and subsequent drying. Most interesting is the relationship of groundwater levels in relationship to stage at Cusick and Ione during the period of peak flow. During this period, the gates at Box Canyon Dam began to open as flow exceeded 62,000 cfs, and became fully open as flow exceeded 90,000 cfs. Stage upstream at Ione dropped by approximately six feet over the course of several days. However, river stage at Cusick near this monitoring well site continued to rise, essentially unaffected by conditions at the Dam with rising river flows, and groundwater within the monitoring wells did not respond to the drop at Ione. Groundwater levels in monitoring well A (closest to the river) mirrors stage effects at Cusick, where stage is controlled by river flows, and not by operation of Box Canyon Dam.

Figures 3 and 4 illustrate similar relationships for the PowWow Grounds and Calispell Creek wells. Note for all sites that the greatest groundwater gradient potentially affecting stability of streambanks (represented by the difference in elevation between monitoring well A and river stage) occurs during the early spring prior to peak flows, when river flows are relatively low (and stable), and also when groundwater levels have risen appreciably due to precipitation, melting snow, or groundwater from upland sources. Groundwater levels during these conditions are unaffected by the reservoir.

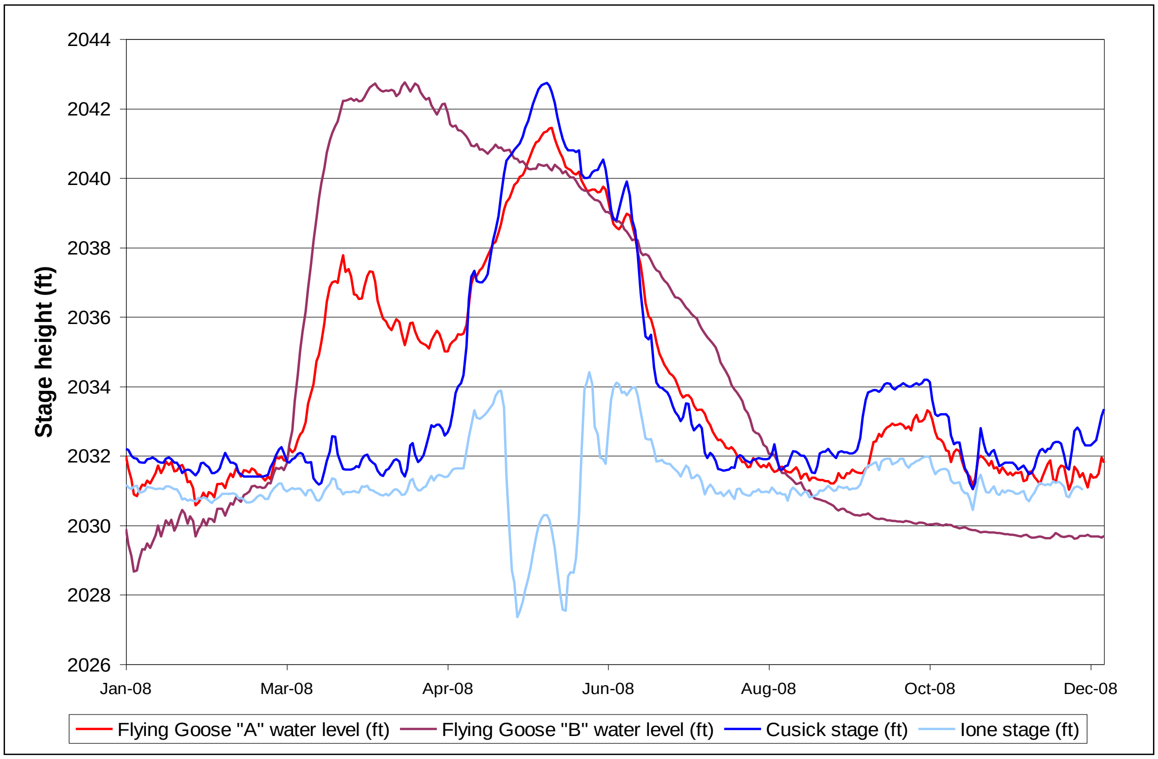

Figure 2. Groundwater at the Flying Goose (RM 64.0R) Groundwater Monitoring Wells in Relation to Stage at Ione (RM 37) and at Cusick (RM 70) During Drawdown at Box Canyon Dam, 2008 (preliminary data).

Monitoring well A is closest to the river.

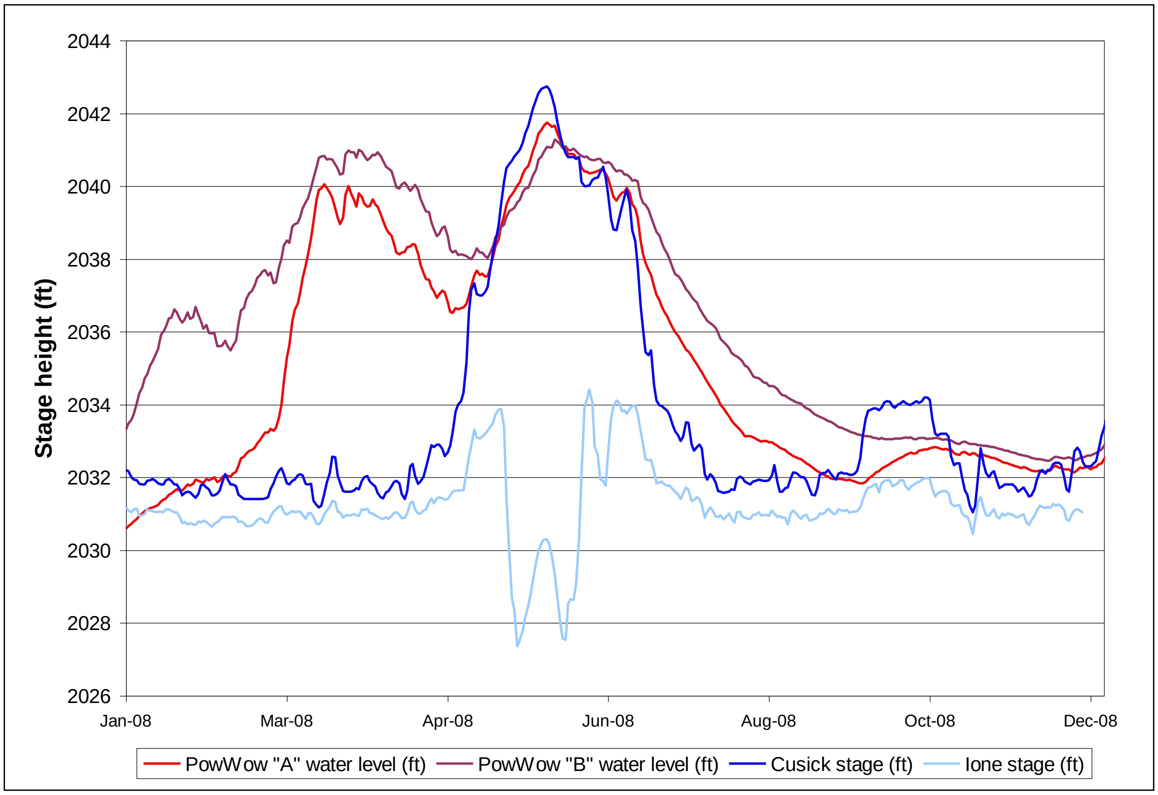

Figure 3. Groundwater at the PowWow Grounds (RM 69.7) Groundwater Monitoring Wells in Relation to Stage at Ione (RM 37) and at Cusick (RM 70) During Drawdown at Box Canyon Dam, 2008 (preliminary data).

Monitoring well A is closest to the river.

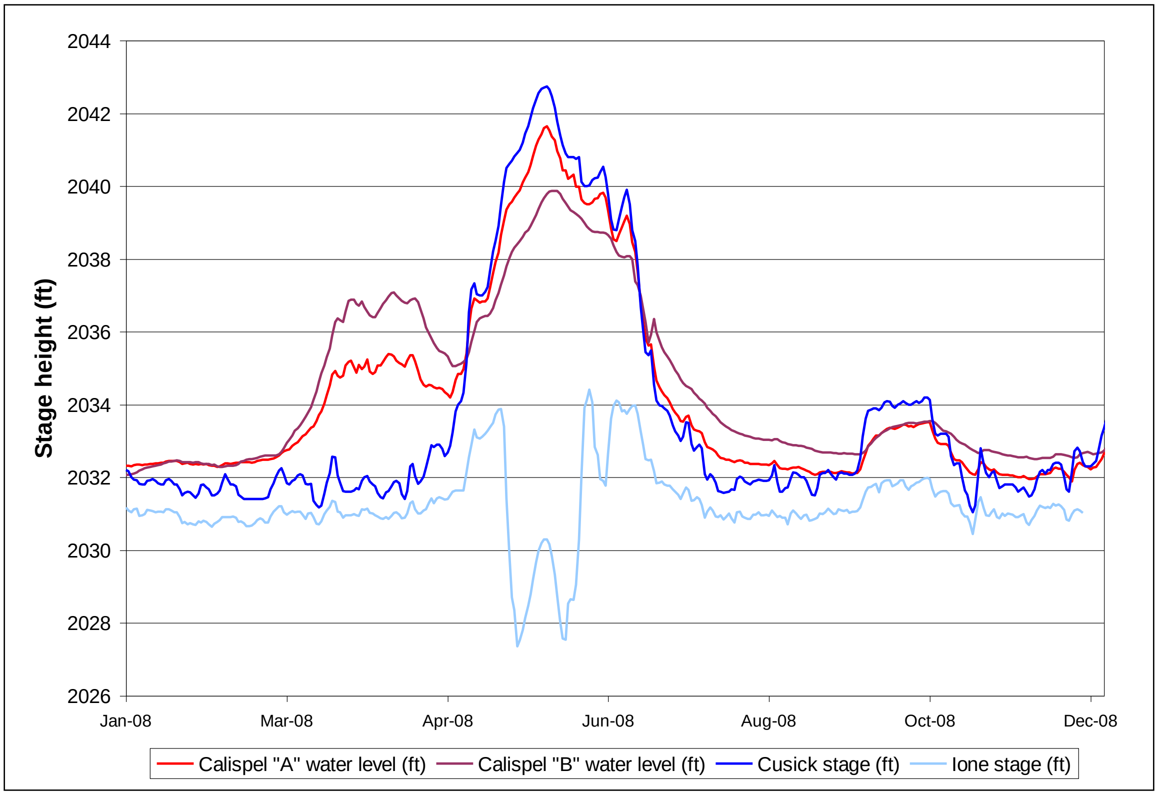

Figure 4. Groundwater at the Calispell Creek (RM 69.8L) Groundwater Monitoring Wells in Relation to Stage at Ione (RM 37) and at Cusick (RM 70) During Drawdown at Box Canyon Dam, 2008 (preliminary data).
Monitoring well A is closest to the river.

These relationships indicate that drawdown at Box Canyon Dam in compliance with the License is unlikely to have any detectable effect on groundwater or slope stability relationships on KIR shorelines. Nevertheless, emergency drawdown at Box Canyon Dam could potentially cause drawdown-related groundwater effects, as could rapidly decreasing river flows into Box Canyon Reservoir. Accordingly, drawdown of groundwater levels was simulated at each of the groundwater monitoring sites.

SOIL CHARACTERISTICS OF KIR SHORELINES AND AT THE GROUNDWATER MONITORING SITES

The entirety of KIR shorelines lie within the Cusick Basin. Soils within the Basin formed as silty and clayey sediments deposited within a recessional lake associated with retreat of the Spokane Lobe of the Cordilleran Ice Sheet. The soils maps in the Soil Survey of Pend Oreille County (Donaldson et al. 1992) show that approximately 90% of the entire KIR shoreline is mapped as two soil types: Cusick silty clay loam, and Blueslide silt loam. Soils found at the groundwater monitoring sites, as described below, conform to the general description for Basin soils - stratified, silty, and clayey sediments – and vary from one another only to a limited degree, and are representative of soils found along KIR shorelines.

Soils surrounding the Flying Goose site (erosion monitoring site 57; Figure 5) are mapped as Blueslide Silt Loam, described as very deep, moderately well drained silt loam overlying silty clay loam or silty sand on terraces with moderately slow permeability (Donaldson et al. 1992). Soil strata described from core drilling conform to this general description (Budinger and Associates 2007).

Figure 5. Site 57, RM 64.0R.

Soils surrounding the PowWow Grounds site (erosion monitoring site 52, RM 69.7 right bank; Figure 6) are mapped as Anglen Silt Loam, described as very deep, somewhat poorly drained silt loams with minor inclusions of silty clay loam and fine sandy loam with moderately slow permeability (Donaldson et al. 1992). Soil strata described from core drilling conform to this general description (Budinger and Associates 2007).

Figure 6. Site 52 RM 69.7R.

Soils surrounding the Calispell Creek groundwater site (erosion monitoring site 53, RM 69.8 left bank; Figure 7) are mapped as Cusick Silty Clay Loam, the most common soil type mapped for the KIR shorelines. These soils are described as very deep, somewhat poorly drained silty clay loam overlying silty clay with very slow permeability (Donaldson et al. 1992). Soil strata described from core drilling conform to this general description (Budinger and Associates 2007).

Figure 7. Site 53 RM 69.8L

MODELING METHODS

Data Sources

Bank profile geometry at each of the groundwater monitoring sites geometry was obtained from the erosion monitoring surveys conducted in 2009 as reported in the District's 2010 Annual Shoreline Erosion Monitoring Report. River elevations were obtained from stream gauge data recorded by the District at Cusick. Water table elevations were obtained from the groundwater monitoring wells in 2008 and 2009. One well at each site was located approximately 30-50ft from the river bank, and another well was located approximately 110-140ft from the river bank. Soil properties were estimated from soil tests performed by Budinger and Associates (Appendix A) utilizing core samples obtained during the drilling of the monitoring wells in 2007. Soil properties required for input to the modeling include saturated hydraulic conductivity, volumetric water content, bulk density, and soil strength parameters (either cohesion and angle of internal friction, or shear-normal stress relationship). In this case, shear-normal stress functions were used for soil strength relationships, because these curves were available from the well core testing. An example of one of these functions is illustrated in Figure 8. Figure 9 shows an example of how material properties are assigned to soil regions in the model.

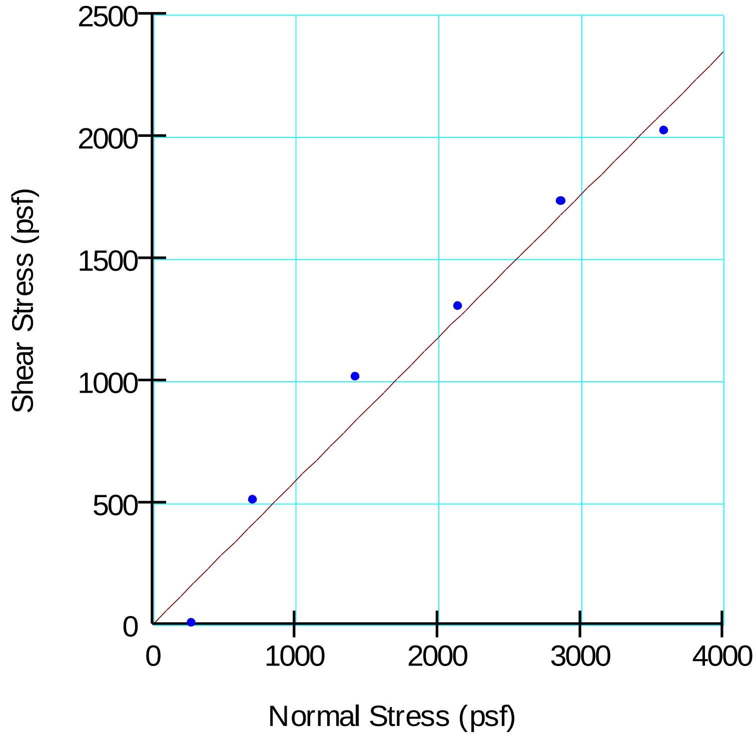

Figure 8. Shear-Normal Stress Relationship for Silty Clay at Calispell Creek Location.

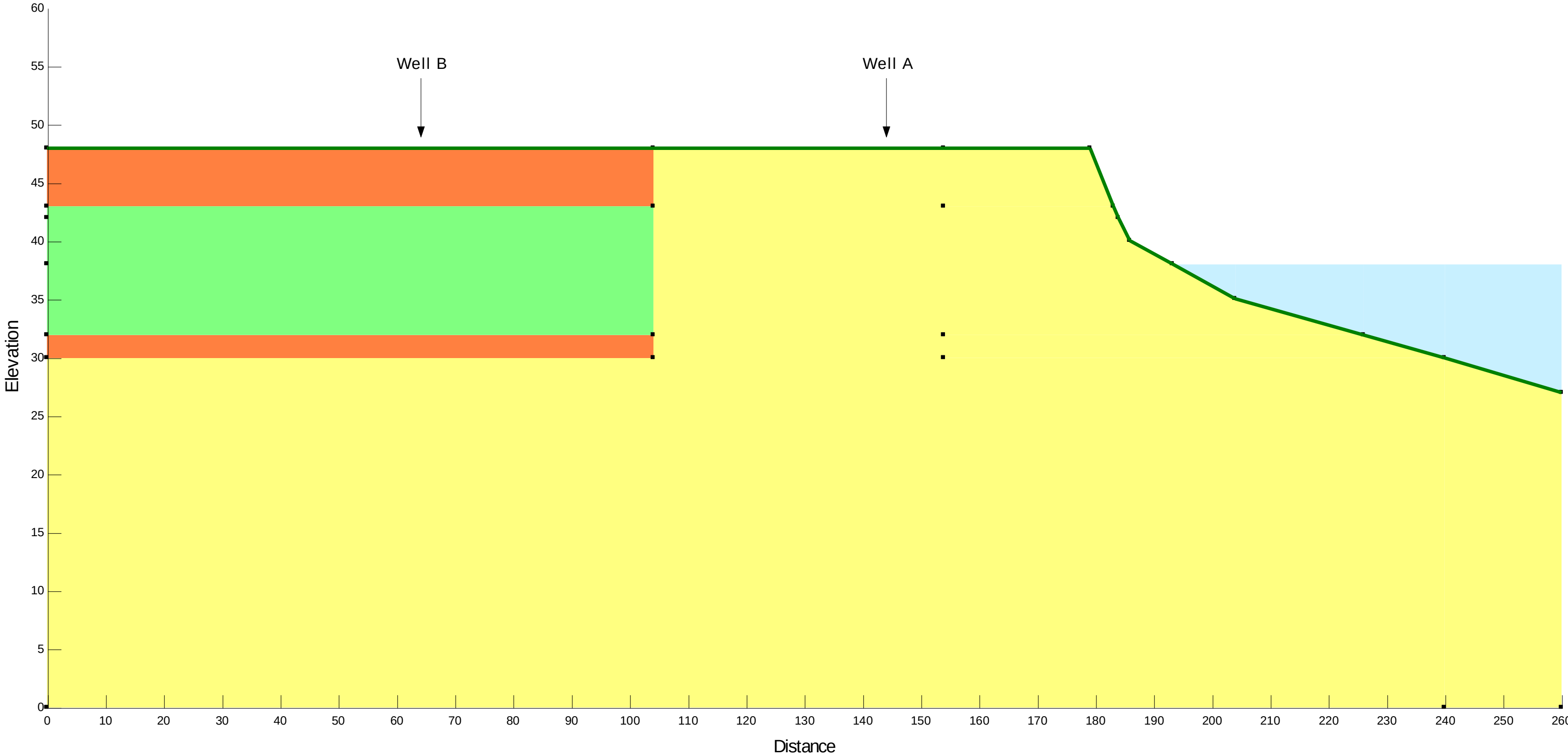

Figure 9. Example of Soil Materials at PowWow Grounds.
Yellow represents silty clay, orange represents silty sand, green represents sandy silt.

Modeling Scenarios

Based on river stage records at Cusick, it was found that maximum stage in 2008 and 2009 was near El 2044, and minimum stage was near El 2032. From the groundwater monitoring well records, it was found that maximum water table gradients (which occurred in the spring of 2008 and 2009) were generally 5-7% near the river's edge. Three different scenarios were then selected for simulation at each location:

- Level water table at El 2038
- Level water table at El 2042
- Water table gradient sloping to El 2032 at the river's edge (consistent with well records)

For each scenario, the initial water table was specified, and then allowed to change over time during drawdown of the river. The maximum drawdown rate specified in the license order is 0.3 feet per hour. The simulations were run for a 6-hour period, beginning with a steady condition at the specified water table, then a 4-hour drawdown at 0.3 feet per hour, followed by two more hours steady at 1.2 feet total drawdown to establish a recovery trend in bank stability.

The modeling was carried out in two stages. First, the SEEP/W model (from Geo-Slope International) was employed to simulate groundwater flow and pore water pressures based on water table, river level, and soil hydraulic properties. The resulting pore water pressures were in turn used as input to the SLOPE/W model (Geo-Slope International) to predict the bank stability factor of safety (FOS) utilizing a limit equilibrium analysis. FOS is an engineering concept applied to structures, and is defined as the ratio of the stress at failure to the estimated maximum stress under ordinary conditions. The higher the FOS, the less likely the structure is to fail. SLOPE/W examines the FOS for many different trial failure surfaces, within the parameters specified by the modeler, and returns the FOS and slip surface resulting in the lowest FOS.

RESULTS

Figure 10 shows a typical output from the SEEP/W model. Figure 11 shows the results from the SLOPE/W model corresponding to the conditions in Figure 10. For each scenario at each location, the FOS was computed at hourly intervals over the 6-hour simulation. These FOS results are summarized for each location in Tables 1-3.

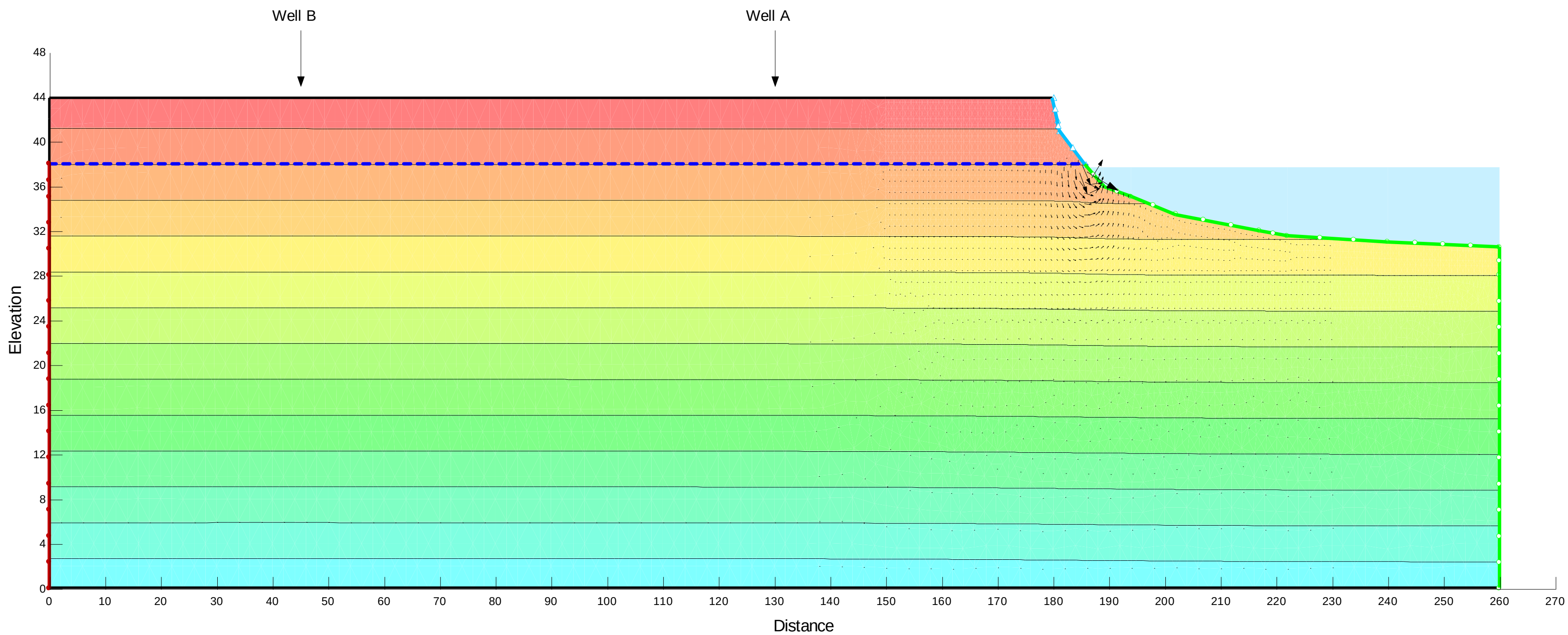

Figure 10. SEEP/W Result for Flying Goose Location after One Hour of Drawdown.
Color shading represents pore water pressure contours. Blue dotted line represents water table surface (El 2038). Arrows represent water flow (direction and magnitude). Green circles at right represent river level boundary condition (total head as a function of time). Red circles at left represent water table at constant total head of 38ft. Blue triangles (upper bank) represent potential seepage face.

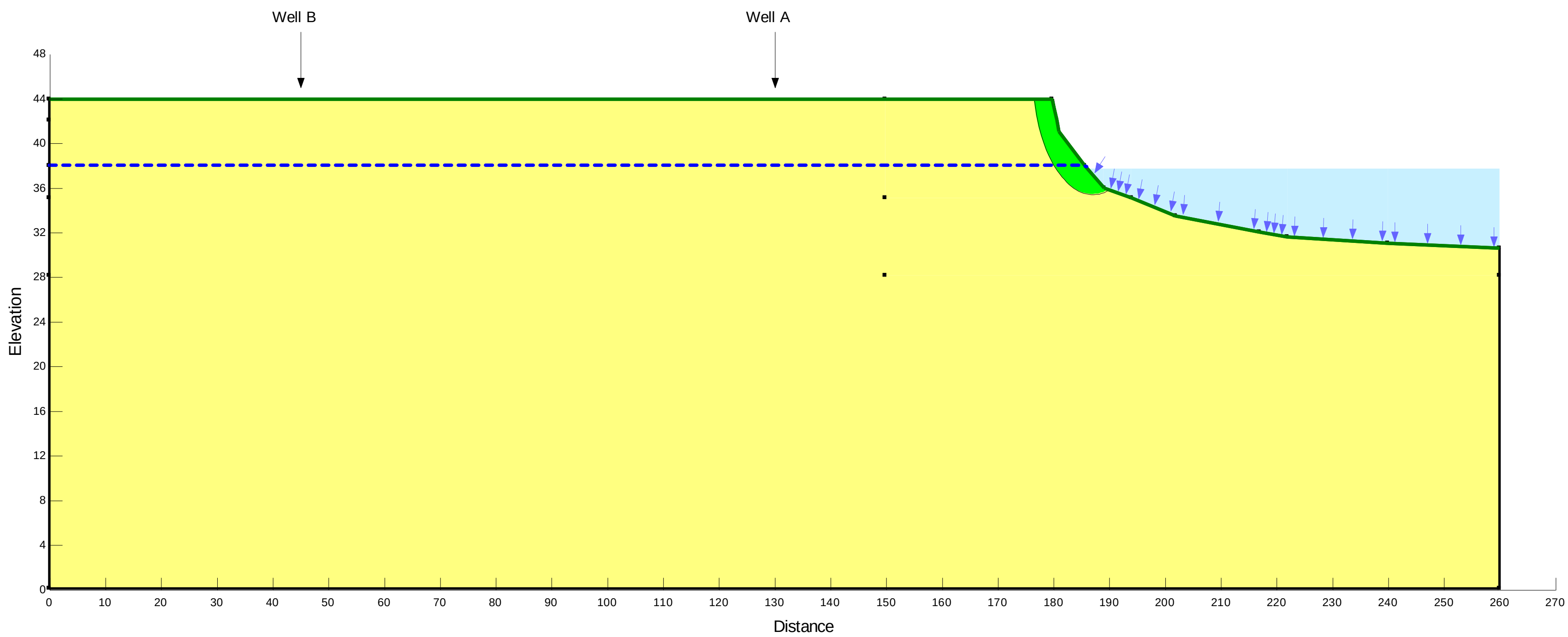

Figure 11. SLOPE/W Result Corresponding to SEEP/W Result in Figure 10 for Flying Goose Location. Blue dotted line represents water table surface (El 2038). Green shading represents critical slip surface (lowest FOS).

Table 1. PowWow Grounds Bank Stability Factor of Safety				
		Water Table Condition		
		El 2038	El 2042	Gradient to El 2032
Time (hrs)	**Total drawdown (ft)**	**Factor of Safety**		
0	0	2.712	2.843	2.726
1	0.3	2.687	2.798	2.718
2	0.6	2.657	2.764	2.712
3	0.9	2.631	2.743	2.709
4	1.2	2.611	2.723	2.704
5	1.2	2.614	2.727	2.704
6	1.2	2.615	2.730	2.705

Table 2. Calispell Creek Bank Stability Factor of Safety				
		Water Table Condition		
		El 2038	El 2042	Gradient to El 2032
Time (hrs)	**Total drawdown (ft)**	**Factor of Safety**		
0	0	1.903	2.139	1.780
1	0.3	1.875	2.098	1.768
2	0.6	1.849	2.058	1.758
3	0.9	1.824	2.020	1.750
4	1.2	1.801	1.987	1.743
5	1.2	1.802	1.987	1.743
6	1.2	1.802	1.987	1.744

Table 3. Flying Goose Bank Stability Factor of Safety				
		Water Table Condition		
		El 2038	El 2042	Gradient to El 2032
Time (hrs)	**Total drawdown (ft)**	**Factor of Safety**		
0	0	1.465	1.840	1.554
1	0.3	1.427	1.740	1.554
2	0.6	1.397	1.660	1.554
3	0.9	1.372	1.573	1.554
4	1.2	1.357	1.502	1.554
5	1.2	1.358	1.502	1.554
6	1.2	1.359	1.503	1.554

Sensitivity

Due to the time and expense of soil testing procedures, material properties were tested on a limited number of soil samples from the well cores. The soil parameters input to the model were best estimates based on the limited test data available. Therefore, a sensitivity analysis was performed to determine the sensitivity of the results to variability in the material properties.

As mentioned previously, soil properties required by the model are hydraulic conductivity, volumetric water content (including residual water content), bulk density, and soil strength parameters. Variation in hydraulic conductivity affects the rate of groundwater flow. This in turn affects the time it takes for the system to respond, but does not affect the resulting values of head or pore water pressure. Therefore, the values for FOS remain unaffected by changes in hydraulic conductivity, although they could be shifted in time.

Volumetric water content (VWC) is the property of the soil describing the moisture in the soil as a function of suction (negative pore pressure) on the soil. Figure 12 is an example of a VWC function for a silty clay. The maximum value on the right side of the graph is the saturated water content, which is equal to the porosity of the soil. One of the key parameters in this function is the residual water content, i.e., the value at the left side of the graph at high suction (negative pore water pressure). Variation in the RWC is similar to that for hydraulic conductivity. Increasing RWC means that more water is retained in the soil, and therefore less water is drained from the soil during a drawdown situation. This in turn affects the rate of response of the system; increasing RWC will decrease response time. However, it also means that more water is retained in the unsaturated portion of the soil profile, which could affect pore water pressures. Therefore, the effect of changing RWC was examined as a potential source of uncertainty. RWC content at the Flying Goose location was varied from 15% down to 0% for two of the scenarios - water table level at El 2038 and water table level at El 2042. In both cases, FOS valued were unaffected by changes in RWC.

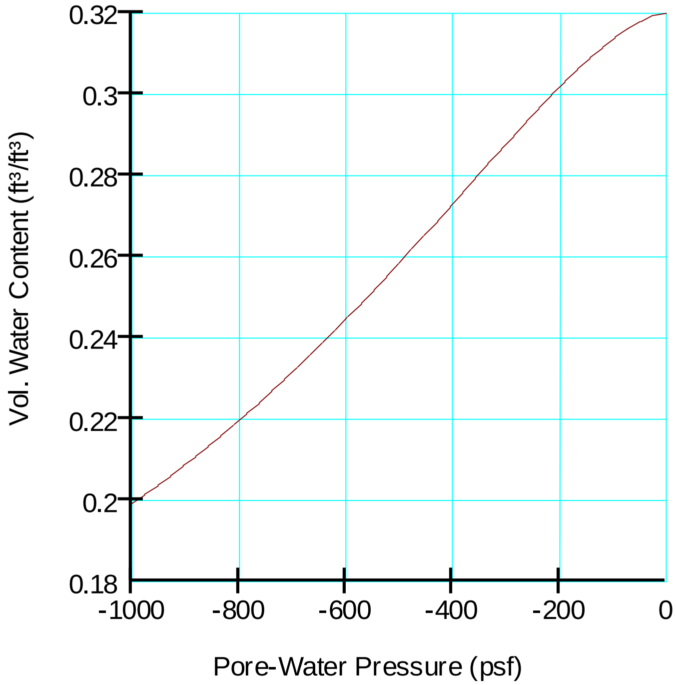

Figure 12. Volumetric Water Content Function Used for Silty Clay at Flying Goose Location.

Soil strength properties are potentially the most likely to significantly affect resulting FOS values. A sensitivity analysis was performed using the scenario with a water table gradient at the Calispell Creek location at time 0 (steady conditions). In this case, initial cohesion and friction angle were set at 300psf and 31°, respectively. Then cohesion was varied over the range of 200-400psf, and friction angle varied from 29°-33°. The resulting sensitivities are illustrated in Figures 13 and 14.[12]

[12] The FOS values shown in Figures 13 and 14 are not directly comparable to the corresponding scenario in Table 2, because the scenario in Table 2 utilized the shear-normal stress relationship derived from soil strength testing, whereas the built-in sensitivity analysis in SLOPE/W uses a Mohr-Coulomb soil strength model.

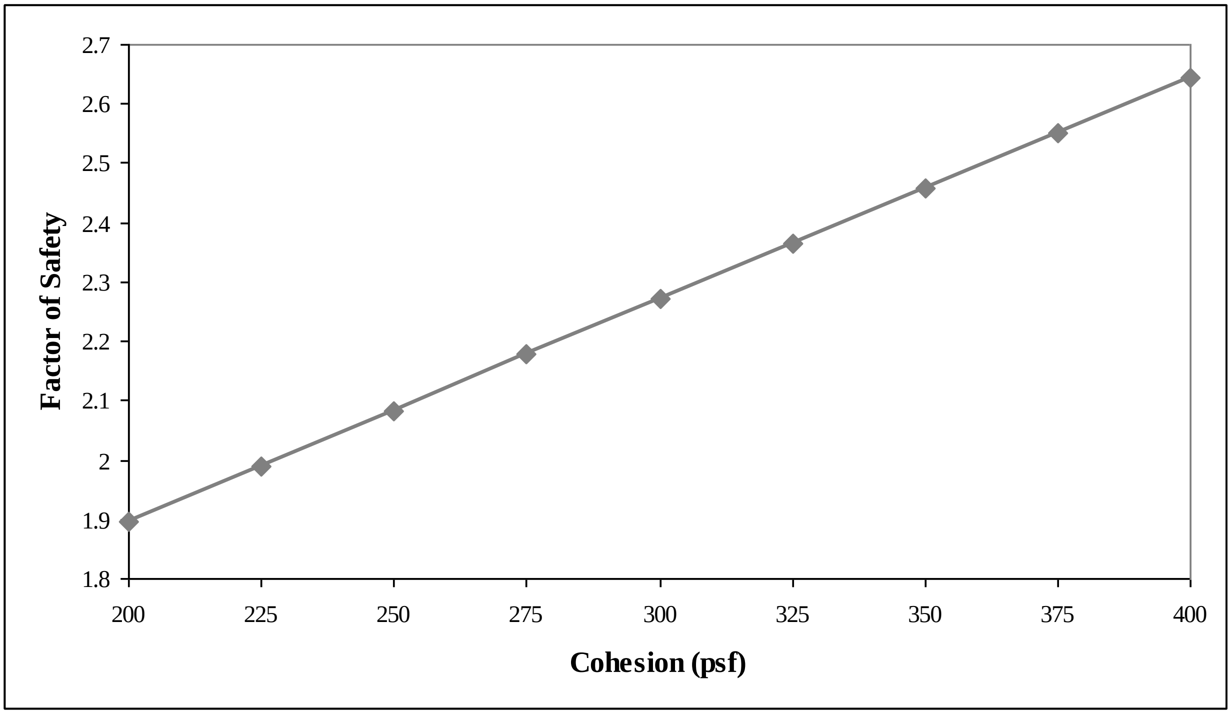

Figure 13. Sensitivity of Factor of Safety to Variation in Cohesion.

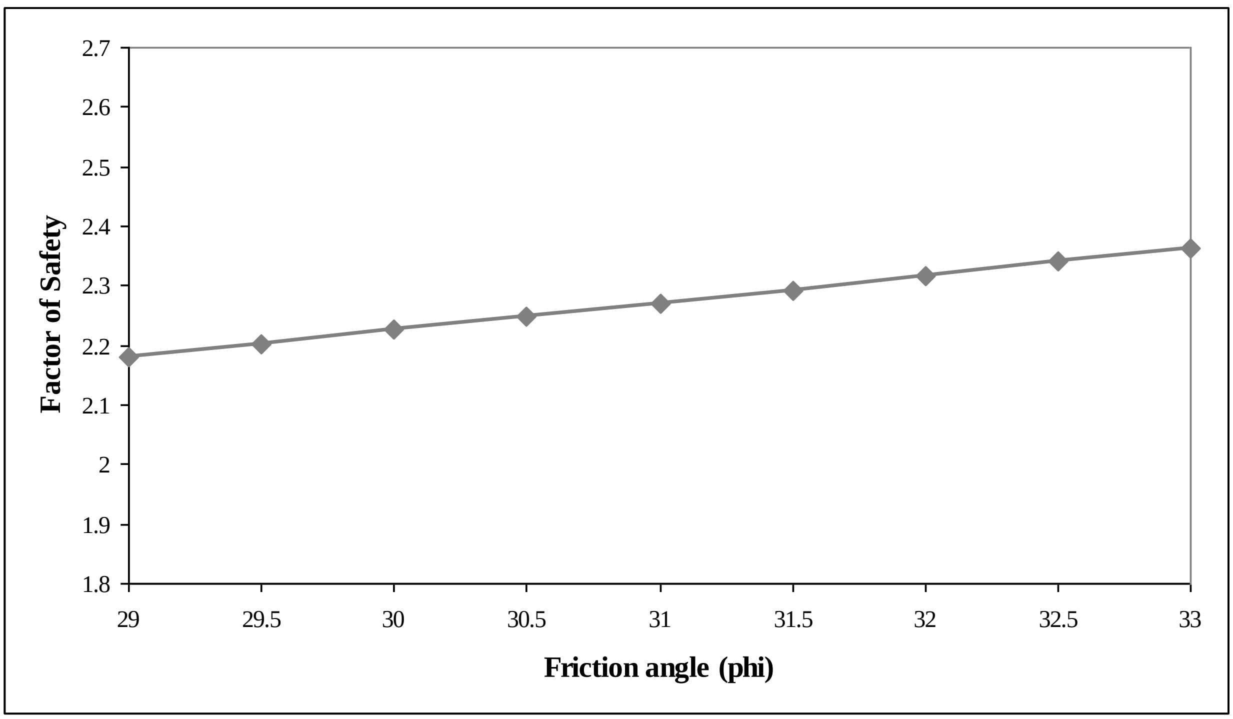

Figure 14. Sensitivity of Factor of Safety to Angle of Internal Friction.

This analysis demonstrates that FOS is much more sensitive to the value used for cohesion than it is to friction angle. However, it should be noted that while uncertainties in soil parameters are inevitable, it is the relative FOS values that are important. That is, the comparison between steady conditions (at time 0 in Tables 1-3) and drawdown conditions (1 hour to 4 hours in Tables 1-3) is the information of crucial interest. While FOS values yielded by the analysis vary with soil properties, the relative change of FOS as affected by drawdown remains essentially unchanged.

DISCUSSION AND CONCLUSIONS

Results of these simulations suggest that the Flying Goose location is the least stable of the three, and the PowWow Grounds is the most stable of the three. This is consistent with field observations at Flying Goose, where erosion and sloughing of the bank is evident. Flying Goose also has the least cohesive soils. On the other end of the spectrum, the PowWow Grounds location has the least hillslope of the three, and also has the soil with the greatest cohesion, and therefore exhibits less chance of failure. The shoreline embankment surrounding this site is also heavily vegetated with deep-rooted shrubs and small trees, which may further contribute to slope stability, a factor which was not simulated.

In all scenarios, FOS decreased with continuing drawdown, but leveled out and started to recover after drawdown ceased, which is what would be expected. However, the magnitude of change in FOS varies with the situation. At all locations, the most stable condition was with a level water table at El 2042. This is because when the river level is high, pore water pressure stabilizes the soil structure. However, this also means that this is the condition most susceptible to effects of drawdown, which is corroborated by the numbers shown in Tables 1-3 - the greatest changes in FOS during drawdown occur for this situation. The scenarios with water table at El 2038 are the next most susceptible to drawdown effects, and the low water table scenario least susceptible (water table gradient sloping to El 2032 at the water's edge).

The greatest change in FOS occurs for the scenario at the Flying Goose location with water table at El 2042, where FOS changes by 0.338 (18.4%) after four hours of drawdown. Again, this could be expected, given the unstable condition of the banks at this location. All of the other scenarios resulted in substantially smaller changes in FOS, ranging from 0 (0%) to 0.152 (7.1%). The one scenario resulting in no change in FOS was at the Flying Goose location with a water table gradient. This is due to the fact that the critical failure surface in this case is well above the water table, and therefore changes in groundwater flow have negligible effects on the critical failure surface (see Figure 15).

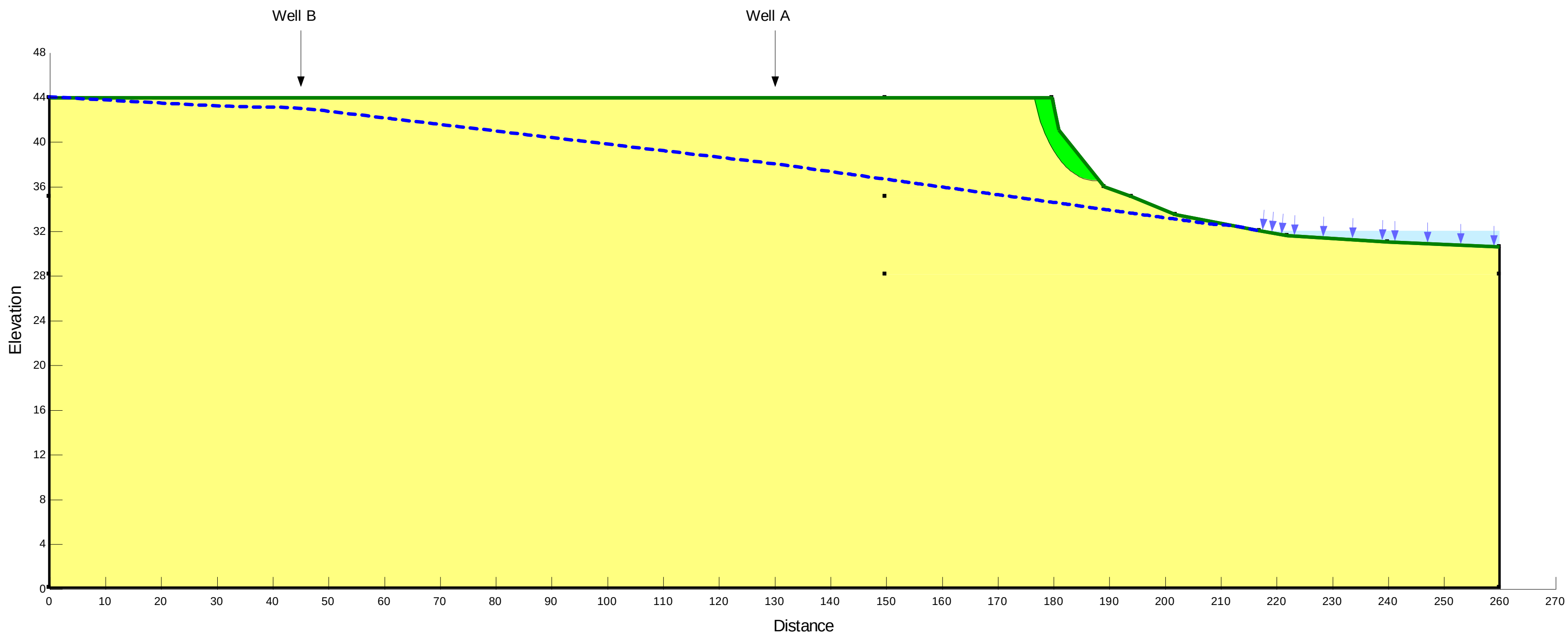

Figure 15. SLOPE/W Result for Flying Goose Location with Water Table Gradient.
Blue dotted line represents water table surface. Green shading represents critical slip surface (lowest FOS).

Putting the final results in perspective, the modeled changes in bank FOS due to drawdown effects are relatively small. In all but one case, change in FOS is on the order 0.1 or less (7% or less). The worst case results in a change in FOS of 0.34 (18%). It is unlikely that drawdown rates of 0.3 feet per hour substantially affect bank stability along Box Canyon Reservoir. Moreover, the groundwater and river stage data developed for this study indicate that drawdown at Box Canyon Dam in compliance with the License is unlikely to have any detectable effect on groundwater or slope stability relationships on KIR shorelines. Nevertheless, emergency drawdown at Box Canyon Dam, or rapidly decreasing river flows into Box Canyon Reservoir, could potentially cause drawdown-related groundwater effects similar to those represented by these simulations.

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Dale J. McGreer, P.G.

Dale J McGreer